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AN

INTRODUCTION

TO

BOTANY.

BY

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PREFACE.

About three centuries have elapsed since one of the earliest introductions to Botany upon record was published, in four pages folio, by Leonhart Fuchs, a learned physician of Tubingen. At that period Botany was nothing more than the art of distinguishing one plant from another, and of remembering the medical qualities, sometimes real, but more frequently imaginary, which experience, or error, or superstition, had ascribed to them. Little was known of Vegetable Physiology, nothing of Vegetable Anatomy, and even the mode of arranging species systematically had still to be discovered; while scarcely a trace existed of those modern views which have raised the science from the mere business of the herb-gatherer to a station among the most intellectual branches of natural philosophy.

It now comprehends a knowledge not only of the names and uses of plants, but of their external and internal organisation, their anatomy and physiological phenomena: it involves the consideration of the plan upon which those multitudes of vegetable forms that clothe the earth have been created, of the combinations out of which so many various organs have emanated, of the laws that regulate the dispersion and location of species, and of the influence exercised by climate upon their developement; and, lastly, from botany as now understood, in its most extensive signification, is inseparable the knowledge of the various ways in which the laws of vegetable life are applicable to the augmentation of the luxuries and comforts, or to the diminution of the wants and miseries, of mankind. It is by no means, as some suppose, a science for the idle philosopher in his closet; nor is it merely an amusing accomplishment, as others appear to think; on the contrary, its field is in the midst of meadows, and gardens, and forests, on the sides of mountains, and in the depths of mines, — wherever vegetation still flourishes, or wherever it attests by its remains the existence of a former world. It is the science which converts the useless or noxious weed into the nutritious vegetable; which changes a bare volcanic rock into a green and fertile island; and which enables the man of science, by the power it gives him of judging how far the productions of one climate are susceptible of cultivation in another, to guide the colonist in his enterprises, and to save him from those errors and losses into which all such persons unacquainted with Botany are liable to fall. This science, finally, it is which teaches the physician how to discover in every region the medicines that are best adapted for the maladies prevalent in it; and which, by furnishing him with a certain clue to the knowledge of the tribes in which particular properties are, or are not, to be found, renders him as much at ease, alone and seemingly without resources, in a land of unknown herbs, as if he were in the midst of a magazine of drugs in some civilised country.

The principles of such a science must necessarily be complicated, and in certain branches, which have only for a short time occupied the attention of observers, or which depend upon obscure and ill-understood evidence, are less clearly defined than could be wished. To explain those principles; to adduce the evidence by which their truth is supposed to be proved, or the reasoning upon which they are based in cases where direct proof is unattainable; to show the causes of errors now exploded, the insufficiency of the arguments by which doubtful theories are still defended, and, in fine, to draw a line between what is certain and what is doubtful, are some of the objects of this publication, which is intended for the use of those who, without being willing to occupy themselves with a detailed examination of the vast mass of evidence upon which the modern science of botany is founded, are, nevertheless, anxious to acquire a distinct idea of the nature of that evidence. Another and not less important purpose has been to demonstrate, by a series of well-connected proofs, that in no department of natural history are the simplicity and harmony that pervade the universe more strikingly manifest than in the vegetable kingdom, where the most varied forms are produced by the combination of a very small number of distinct organs, and the most important phenomena are distinctly explained by a few simple laws of life and structure.

In the execution of these objects, I have followed very nearly the method recommended by the celebrated Professor De Candolle, than whom no man is entitled to more deference, whether you consider the soundness of his judgment in all that relates to order and arrangement, or the great experience which a long and most successful career of public instruction has necessarily given him.

I have begun with what is called ORGANOGRAPHY (Book I.); or an explanation of the exact structure of plants; a branch of the subject comprehending what relates either to the various forms of tissue of which vegetables are constructed, or to the external appearance their elementary organs assume in a state of combination. It is exceedingly desirable that these topics should be well understood, because they form the basis of all other parts of the science. In physiology, every function is executed through the agency of the organs: systematic arrangements depend upon characters arising out of their consideration; and descriptive Botany can have no logical precision until the principles of Organography are exactly settled. A difference of opinion exists among the most distinguished botanists, upon some points connected with this subject, so that it has been found expedient to enter occasionally into much detail, for the purpose of satisfying the student of the accuracy of the facts and reasonings upon which he is expected to rely.

To this succeeds VEGETABLE PHYSIOLOGY (Book II.); or the History of the vital phenomena that have been observed both in plants in general, and in particular species, and also in each of their organs taken separately. It is that part of the science which has the most direct bearing upon practical objects. Its laws, however, are either unintelligible, or susceptible of no exact appreciation, without a previous acquaintance with the more important details of Organography. Much of the subject is at present involved in doubt, and the accuracy of some of the conclusions of physiologists is inferred rather than demonstrated; so that it has been found essential that the grounds of the more popularly received opinions, whether admitted as true or rejected as erroneous, should be given at length.

Next follows GLOSSOLOGY (Book III.); or, as it was formerly called, TERMINOLOGY; restricted to the definition of the adjective terms, which are either used exclusively in Botany, or which are employed in that science in some particular and unusual sense. The key to this book, and also to the substantive terms explained in Organography, will be found in a copious index at the end of the volume.

These topics exhaust the science considered only with reference to first principles; there is, however, another which it has been thought advisable to append, on account of its practical value, namely PHYTOGRAPHY (Book IV.); or, an exposition of the rules to be observed in describing and naming plants. As the great object of descriptions in natural history, is to enable every person to recognise a known species, after its station has been discovered by classification, and also to put those who have not had the opportunity of examining a plant themselves into possession of all the facts necessary to acquire a just notion of its structure and affinities; it is indispensable that the principles of making descriptions should be clearly understood, both to prevent their being too general to answer the intended purpose, or more prolix than is really requisite. It is the want of a knowledge of these rules that renders the short descriptions of the classical writers of antiquity, and the longer ones of many a modern traveller, equally vague and unintelligible. In this place are inserted a few notes upon the formation of an herbarium.

It has been my wish to bring every subject that I have introduced down, as nearly as possible, to the state in which it is found at the present day. In doing so, I have added so very considerable a quantity of new matter, especially in what relates to

Vegetable Anatomy and Physiology, that the present edition may be considered, in those respects, a new work.

In the statements I have made, it has been my wish to render due credit to all persons for the discoveries by which they may severally have contributed to the advancement of the science; and if I have on any occasion either omitted to do so, or assumed to myself observations which belong to others, it has been unknowingly or inadvertently. It is, however, impracticable, and if practicable it would not be worth while, to remember upon all occasions from what particular sources information may have been derived. Discoveries, when once communicated to the world, become public property: they are thrown into the common stock for mutual benefit; and it is only in the case of debatable opinions, or of any recent and unconfirmed observations, that it really interests the world that authorities should be quoted at all. In the language of a highly valued friend, when writing upon another subject, —"The advanced state of a science is but the accumulation of the discoveries and inventions of many: to refer each of these to its author is the business of the history of science, but does not belong to a work which professes merely to give an account of the science as it is: all that is generally acknowledged must pass current from author to author."*

London, May, 1839.

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* Brett's Principles of Astronomy, p. v.

CONTENTS.

Page

BOOK I. — ORGANOGRAPHY.

CHAP. I. Elementary Organs 1
Consist of Membrane 3
—— Fibre 6
SECT. I. Cellular Tissue, or Parenchyma 9
—— Membranous 13
—— Fibrous 15
Cytoblast 19
SECT. II. Pitted Tissue, or Bothrenchyma 21
—— Articulated 21
—— Continuous 22
SECT. III. Woody Tissue, or Pleurenchyma 22
—— Glandular 25
SECT. IV. Vascular Tissue, or Trachenchyma.
Spiral Vessels 27
Ducts 33
SECT. V. Laticiferous Tissue, or Cinenchyma 35
SECT. VI. Spurious Elementary Organs.
Intercellular Passages 37
Receptacles of Secretion 38
Air Cells 39
Raphides 41
Biforines 43
SECT. VII. Amylaceous and Granular Matter.
Amylaceous Granules 43
Chlorophyll 46
Latex Granules 47
CHAP. II. Compound Organs in Flowering Plants.
SECT. I. Epidermis and Appendages.
Epidermis 48
Stomates 51
Hairs 59
Scurf 63
Glands 64
Prickles 68
SECT. II. Stem, or ascending Axis 69
Branches 71

Page
Leaf-buds 73
Bulbs 77
Embryo Buds 79
Subterranean Stems 80
Internal Structure 85
Exogens 86
Anomalous Exogens 96
Endogens 102
SECT. III. Root or descending Axis 108
SECT. IV. Appendages of the Axis 110
Leaves 112
—— Spiral Arrangement 114
—— Anatomy 121
—— Veins 129
—— Forms 134
—— Petiole 138
Phyllodia 140
Tendril 140
Pitchers 141
Spines 142
Stipules 143
Bracts 146
Flower 151
Inflorescence 152
Calyx 161
Corolla 166
Stamens 171
Pollen 181
Disk 192
Pistil 193
Receptacle 210
Ovule 211
Fruit 221
Classification of Fruits 234
Seed 242
Albumen 249
Embryo 249
Germination 250. 252
Naked Seeds 257
CHAP. III. Compound Organs in Flowerless Plants, or Acrogens 258
Ferns 258
Equisetaceæ 262
Lycopodiaceæ 262
Marsileaceæ 263

Page
Mosses and Andræaceæ - 265
Jungermanniaceæ and Hepaticæ - - - 268
Lichens - - - 270
Algaceæ - - - 272
Fungaceæ - - 274

BOOK II. — PHYSIOLOGY.

General Considerations - 277
CHAP. I. Chemical Constitution of Elementary Organs - 289
CHAP. Elementary Organs - 296
CHAP. III. Symmetry - 302
CHAP. IV. Root - - - 304
CHAP. V. Stem and Origin of Wood - - - 309
CHAP. VI. Leaves - - 324
CHAP. VII. Bracts - - 330
Calyx and Corolla - 330
Disengagement of Caloric - 333
CHAP. VIII. Fertilisation - 337
Sexuality of Plants denied - 345
Mules - - - 348
CHAP. IX. Fruit - - 351
Changes during ripening - 354
Bletting - - - 356
CHAP. X. Seeds - - 358
Their Longevity - - 358
Germination - 359. 363
Respiration - - 360
Action of Heat - - 361
CHAP. XI. Food of Plants - 366
Carbon - - - 366
Water - - - 367
Nitrogen - - 368
Power of Solution - 369
Exhaustion of Soil - 370
Manures - - - 371
CHAP. XII. Digestion - - 372
Decomposition of Carbonic Acid - - - 373
Fungi - - - 378
Hydrogen - - 379
Nitrogen - - - 379
Foreign Matter - - 380
Light - - - 382
Excretions - - - 383
Nitrogen - - 385
Hydrogen - - - 385
Sulphurous Acid Gas - 385
Muriatic Acid Gas - 386
Chlorine - - 386
Nitrous Acid Gas - 386
Sulphuretted Hydrogen - 386
Ammonia - - - 387
Cyanogen - - 387
Carbonic Oxide - - 387
Olefiant Gas - - 388
Protoxide of Nitrogen - 388
Page
Hydrocyanic Acid - 388
CHAP. XIII. Circulation - 389
Perspiration - - 389
Rotation - - - 391
Cyclosis - - 393
Course of Sap - - 400
Circulating Vessels - 401
Cause of Motion - - 402
CHAP. XIV. Directions - 406
CHAP. XV. Irritability - 418
Poisons - - - 419
CHAP. XVI. Colour - - 427
Chlorophyll - - 429
Xanthic and Cyanic Series - 432
Marquart's Views - - 434
CHAP. XVII. Odours - 438

BOOK III. — GLOSSOLOGY.

Absolute Terms - - 445
—— of Figure - - 446
—— of Outline - - 455
—— of Apex - - 458
—— of Marginal Division - 460
—— of Incision - - 461
—— of Composition - 463
—— of Marking or Evenness - - - 467
—— of Superficial Appendages - - - 468
—— of Polish or Surface 471
—— of Texture or Substance 471
—— of Size - - 473
—— of Duration - - 475
—— of Colour - - 477
—— of Variegation - 481
—— of Veining - - 482
Relative Terms - - 483
—— Estivation - - 483
—— Direction - - 485
—— Insertion - - 489
Collective Terms - 491
—— Arrangement - 491
—— Number - - 495
Qualifying Terms - 496
Signs - - - 496
Abbreviations - - 499

BOOK IV. — PHYTOGRAPHY.

CHAP. I. Diagnoses - - 507
Differential Characters - 508
Essential Characters - 508
CHAP. Descriptions - 514
CHAP. III. Punctuation - 526
CHAP. IV. Nomenclature - 528
Terminology - - 532
CHAP. V. Synonyms - - 534
CHAP. VI. Herbaria - - 537
CHAP. VII. Botanical Drawings 544

	Page
APPENDIX - - -	547
Sphagnum pores	547
Spiral Vessels -	547
Raphides -	548
Starch - -	557
Salep - -	557
Stomates -	558
Morphology of Leguminosæ	558
Ovule of Loranthaceæ, &c.	558
Spermatic Animalcules	558
Cellulose - -	558
Mistletoe Impregnation	558
Nutritive Action of Starch	559
Manures - -	559
Nitrogen -	559
EXPLANATION OF PLATES -	561

INTRODUCTION
TO
BOTANY.

BOOK I.

ORGANOGRAPHY; OR, OF THE STRUCTURE OF PLANTS.

CHAPTER I.

OF THE ELEMENTARY ORGANS.

If plants are considered with reference to their internal organization, they appear at first sight to consist of a vast multitude of exceedingly minute cavities, separated by a membranous substance; more exactly examined, it is found that these cavities have a variety of different figures, and that each is closed up from those that surround it; if the inquiry is carried still farther, it will be discovered that the partitions between the cavities are all double, and that by maceration in water, or by other methods, the cavities with their enclosing membrane may be separated from each other into distinct bodies. These bodies constitute what is called Vegetable Tissue, or Elementary Organs: they are the *Similary parts* of Grew.

The chemical basis of the elementary organs has been found to be oxygen, hydrogen, and carbon, with occasionally nitrogen or azote, combined in various proportions: their organic basis is solidified *mucus*, either in an independent state, or organized in the form of *membrane* and *fibre*.

Organic mucus has only lately been recognised as the primitive condition of vegetable tissue; although it has long been known as a substance existing in Algaceous plants, prior to the appearance of organization, as in Protococcus nivalis, &c. It has been found by Brongniart, Henslow, &c. in the form of a thin homogeneous membrane, applied to the cuticle of the leaves of some plants, and only separable after maceration; it is probable that it constitutes the whole exterior surface of all plants, and that it is even drawn over the sacs which constitute hairs; I have found it distinctly on the petals of Hydrotænia meleagris (see Bot. Reg. 1838. misc. No. 128.), but its extreme tenuity and firm adhesion to the tissue below it renders it difficult to detect it; and there is no doubt that it occurs very generally in the interior of plants between their cells, filling up the intercellular spaces, and gluing together all the parts. Mohl, with his usual skill, has shown that this substance is found so frequently, that we cannot refuse to acknowledge its presence as a constant fact. The Box, and the young annual shoots of Sambucus nigra, are especially noticed as well suited to show this structure; it will be seen to form a considerable part of the mass of the albumen of Alstromeria salsilla, see fig. 2. *c.* where it is $\frac{1}{3300}$ of an inch in diameter. Valentin has measured the thickness of the intercellular organic mucus in several instances, and gives the following table of the proportion between it and the cells of certain plants, calculated in Paris inches.

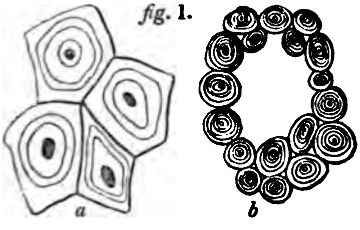
	Thickness of the intercellular mucus.	Size of the cell.	Proportion of the 1st to the 2d.
Camellia Japonica -	0,000112	0,000675	1 : 6,02
Hoya carnosa - -	0,000150	0,000650	1 : 4,33
Magnolia grandiflora -	0,000150	0,000425	1 : 2,83
Cestrum laurifolium -	0,000275	0,001550	1 : 5,63
Daphne Laureola - -	0,000390	0,001000	1 : 2,56
Pinus Picea - -	0,000450	0,001200	1 : 2,66
Aloe intermedia - -	0,000775	0,002100	1 : 2,71
Aloe lingua - -	0,000825	0,002575	1 : 3,12
Agave Americana - -	0,000850	0,002375	1 : 2,79

Meyen admits the fact of the presence of this intercellular mucus, but considers it a secretion from the sides of the cells. He particularly refers to its condition in the petiole of Beta cycla, in proof of the correctness of that view.

It is the opinion of some anatomists that of membrane and fibre, the latter only is the basis of the tissue of plants: fibre itself being a form of membrane. But we find both the one and the other developed in many of the most imperfectly organized plants, such as Scleroderma and other fungi, and it is difficult to conceive how that can be a mere modification of membrane which is generated independently of it, which has no external resemblance to it, and which in many cases is obviously something superadded.

Membrane varies in its degree of transparency, being occasionally so exceedingly thin as to be scarcely discoverable, except by the little particles that stick to it, or by its refraction of light, but in ferns, some fuci, and other cryptogamic plants, it is brown from its first birth: according to Röper it is green in Viscum album; Link says it is green in the leaves of Ruellia Sabiniana and the petiole of Cycas revoluta; and Meyen mentions its being orange coloured in the petiole of many tropical Orchidaceæ. It is always excessively thin when first generated; and whatever thickness it afterwards acquires must be supposed to be owing to the incorporation or incrustation of secreted matter. This was first observed by Mohl in Palm-trees, where he found a successive addition of strata to the lining of the cavities of the cells; and is apparently an universal occurrence where membrane becomes thickened. But the matter added to membrane is often so homogeneous as to offer no trace of its being deposited concentrically, even when examined by the most powerful microscopes, and I am by no means able to discover the regular lines upon its section which are represented so uniformly by the German anatomists. There can, however, be no doubt that the membrane of the woody tubes of the liber is in many plants thickened successively by the deposit inside of concentric layers of sedimentary matter, as may be seen in Castanea vesca (*fig.* 1.*a*), and Betula alba, and in the

fig. 1.



cells below the stomates of Pinus sylvestris (*fig.* 1. *b*), and there are sufficient traces of it to be found elsewhere to justify the opinion that it is a common mode of increment in thickness. Turpin has remarked that this thickening of the membranous sides of cells by means of a hard sedimentary matter, called by him *Sclerogen*, is what causes the grittiness of the pear, and the boniness of the stone of the peach and plum, in all which the osseous parts were originally membranous. It is, however, by no means in old or woody parts that a thickening of the membrane takes place: it may be observed distinctly in the cells of the corolla of Convolvulus tricolor, and in all probability occurs in any part containing fluid matter exposed to decomposition.

Elementary membrane generally tears readily, as if its component atoms do not cohere with greater force in one direction than another; but I have met with a remarkable instance to the contrary of this in Bromelia nudicaulis, in which the membrane of the cuticle breaks into little teeth of nearly equal width when torn. (Plate I. fig. 6.) Hence it may be conjectured, that what we call primitive membrane is itself the result either of primitive fibres completely consolidated, or of molecules originally disposed in a spiral direction, as Raspail supposes. (*Chim. Org.* p. 85.)

In the membrane of certain plants, as in the liber of the Oleander, in Vinca minor, and others belonging to the families of Apocynaceæ and Asclepiadaceæ, an appearance is discoverable of spiral steep ascending lines, some of which turn to the right, others to the left, thus dividing the surface into a number of minute rhomboidal spaces. Mohl, however, who has made this observation, does not therefore consider with Grew that the membrane is woven together of fibres, but that their appearance is owing to a small difference in the thickness of the cellular membrane: "Perhaps a different arrangement of the molecules at various points, perhaps a small difference in the thickness of the membrane, causes a different refraction of light, precisely in the same way as fibres are visible in badly melted glass." Valentin confirms Mohl's views, and regards all such appearances as caused by the process of lignification.

It is in all cases destitute of visible pores; although, as it is readily permeable by fluids, it must necessarily be furnished with invisible passages. An opinion to the contrary of this has been held by some botanists, who have described the existence of holes or pores in the membrane of tissue, and have even thought they saw a distinct rim to them; but this idea, which originated in imperfect observation with illconstructed glasses, is now generally abandoned. Different explanations have been given of the nature of the supposed pores. Dutrochet asserted them to be grains of semi-transparent matter sticking to the membrane: he found that boiling them in hot nitric acid rendered them opaque, and that treating them with a solution of caustic potash restored their transparency, — a property incompatible with a perforation. Slack believed them to be, in other cases, thin spaces in the sides of tissue, such as might be produced by the adhesion and separation at regular intervals of a thread developed spirally within a membranous sac (*Trans. Soc. Arts*, xlix.). A nearly similar opinion was previously offered by Mohl, who considers the dots on the membrane of tissue to be thinner portions of it. He says it may be distinctly seen by the aid of a powerful microscope that the little circles which are visible on the surface of the tissue of Palm-trees are passages (meatus) in the thickness of the membrane, opening into the cavity of the cells, and closed externally by the membrane itself. He adds, that when dotted tissue is in contact, these passages are placed exactly opposite to each other. (*Martius Palm. Anat.* v. *col.* 2.) The latter is undoubtedly the general cause of the appearance of dots, as has now been ascertained by repeated observations. If a thin section of any vessel or cell, the sides of which appear to be dotted, is placed under a good microscope, it will be found to have the matter deposited on its sides, pierced with short passages, which give the appearance of dotting, because the sides of the membrane are thinner where they are stationed than any where else. (See Plate II. fig. 2.) They are therefore not dots, but *pits*.

Should the observer fail in seeing the pits in their natural state, the application of tincture of iodine to the subject under examination will enable him to discover them readily, with a magnifying power of 350 diameters. But it is by no means to thin transparent tissue that these passages are confined; they are universally present in the sides of the thickest sided tissue, where they form minute *cul de sacs* often branched, and always opening into the interior of the cell. They may be readily found in the gritty tissue of the pear (*fig.* 2. *a*), the stone of the plum *b*, and the compact albumen of seeds. *Fig.* 2. *c* represents them in the albumen of Alströmeria, where they are about $\frac{1}{7300}$ of an inch in diameter.

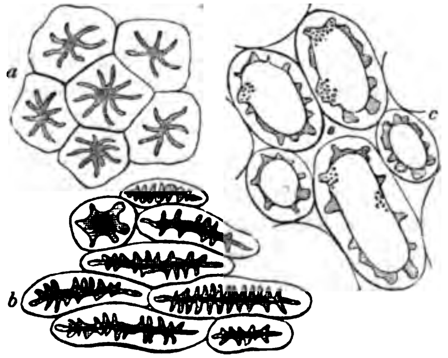


fig. 2.

By what power the sedimentary matter, left on the sides of such tissue as this, is prevented from choking up the pits is at present unknown.

It is, no doubt, very common for the pits of the membrane of one cell to be placed exactly opposite those of the next cell, as is seen in the irregular half gelatinous tissue of Cereus grandiflorus (see Plate II. fig. 1. *a a*), so that it may be supposed that they are passages to allow of permeation from one cell to another; but this arrangement is by no means uniform (see same fig. *b*).*

Elementary Fibre may be compared to hair of inconceivable fineness, but it is extremely variable in size. In Pleurothallis ruscifolia, where it is large, I find it $\frac{1}{3000}$, in Crinum amabile, where it is middle-sized, $\frac{1}{7250}$ of an English inch in diameter. It has frequently a greenish colour, but is more commonly transparent and colourless. It appears to be sometimes capable of extension with the same rapidity as the membrane among which it lies, and to which it usually adheres; but it occasionally elongates less rapidly, when it is broken into minute portions, and is carried along by the growing membrane. In direction it is variable (Plates I. and II.); sometimes it is straight, and attains a considerable length, as in some fungi; sometimes it is short and straight, but hooked at the apex, as in the lining of the anther of Campanula; occasionally it is straight, and adheres to the side of membrane, as in the same part in Digitalis purpurea; but its most common direction is spiral. Whether it is solid or hollow is not quite settled; Purkinje asserts that it is hollow, as will be hereafter mentioned; but there can be no doubt that it is also, at least sometimes, solid, as in the fibrous utricles of the leaf of Oncidium altissimum; and I have every reason to believe that it is always so, an opinion equally entertained by Valentin, Schleiden, and Morren. Elementary Fibre has a constant tendency to anastomose, in consequence of which reticulated appearances are frequently found in tissue. Slack adds that it sometimes branches. Like membrane it is increased in thickness by the deposit of sedimentary matter on that part which does not adhere to the membrane, as has been proved by some beautiful microscopico-chemical experiments of Schleiden.

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* For the supposed chemical difference between elementary membrane and fibre, see Book II. Chapter 1.

Of the organic mucus, membrane, and elementary fibre thus described, all the elementary organs of plants are constructed. For the convenience of description, they may be considered as of five different kinds, 1. *Cellular tissue*, or *Parenchyma*; 2. *Pitted tissue*, or *Bothrenchyma;* 3. *Woody tissue*, or *Pleurenchyma;* 4. *Vascular tissue*, or *Trachenchyma;* 5. *Laticiferous tissue*, or *Cinenchyma.*[*]

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[*] Professor Morren has proposed the following nomenclature of tissue, which has some advantages over that now more commonly in use. I. PARENCHYMA; 1. *merenchyma*, or *sphærenchyma*, spherical; 2. *conenchyma*, conical, as in hairs; 3. *ovenchyma*, oval; 4. *atractenchyma*, fusiform; 5. *cylindrenchyma*, cylindrical; 6. *colpenchyma*, sinuous; 7. *cladenchyma*, branched; 8. *prismenchyma*, prismatical. II. PERENCHYMA, amylaceous granules. III. INENCHYMA, fibro-cellular tissue. IV. ANGIENCHYMA, vascular tissue; 1. *pleurenchyma*, woody tissue; 2. *trachenchyma*, spiral vessels; 3. *modified trachenchyma*, ducts; 4. *cinenchyma*, laticiferous vessels.

There is no doubt that all these forms are in reality modifications of one common type, namely, the simple cell, (according to Morren of an amylaceous granule) however different they may be from each other in station, function, or appearance. For, in the first place, we find them all developed in bodies that originally consisted of nothing but cellular tissue; a seed, for instance, is an aggregation of cells only; after its vital principle has been excited, and it has begun to grow, woody tissue and vessels are generated in abundance. We must, therefore, either admit that all forms of tissue are developed from the simple cell, and are consequently modifications of it; or we must suppose, what we have no right to assume, that plants have a power of spontaneously generating woody, vascular, and laticiferous tissue in the midst of the cellular. Mirbel has lately reduced the first of these suppositions to very nearly a demonstration; in a most admirable memoir on the development of Marchantia he speaks to the following effect. ‘I at first found nothing but a mass of tissue composed of bladders filled with little green balls. Of these some grew into long slender tubes, pointed at each end, and unquestionably adhering by one of their ends to the inside of the sac; others from polygons passed to a spherical form in rounding off their angles. As they grew older, other very important changes took place in certain cells of the ordinary structure, which had not previously undergone any alteration: in each of these there appeared three or four rings placed parallel with each other, adhering to the membrane, from which they were distinguished by their opaqueness; these were altogether analogous to annular ducts. The cells become tubes did not at first differ from other cells in any thing except their form; their sides were uniform, thin, colourless, and transparent; but they soon began to thicken, to lose their transparency, and to be marked all round from end to end with two contiguous parallel streaks disposed spirally. They then enlarged, and their streaks became slits, which cut the sides of the tubes from end to end into two threads, whose circumvolutions separated into the resemblance of a gun-worm.’ In these cases there can, I think, be little doubt that the changes witnessed by

Mirbel were chiefly owing to the developement of a spiral thread in the inside of the tissue; he, however, did not consider it in that light.

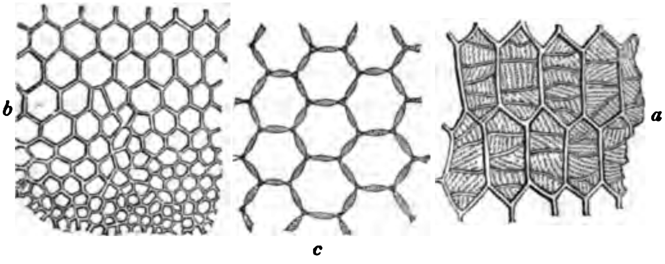
But although the origin of the different forms of tissue may be shown to be identical, it is obviously important to distinguish them for practical purposes. I shall therefore proceed henceforward to speak of them as if they were distinct in their origin.

Sect. I. *Of Cellular Tissue, or Parenchyma.*

Cellular, Utricular, or Vesicular tissue, generally consists of little bladders or vesicles of various figures, adhering together in masses. It is transparent, and in most cases colourless: when it appears otherwise, its colour is caused by matter contained within it.

If a thin slice of the pith of elder, or of any other plant, be examined with a microscope, it will be found to have a sort of honeycomb appearance, as if there were a number of hexagonal cavities, separated by partitions (*fig.* 3.). These little cavities are the inside of bladders of cellular tissue; and the partitions seem to be caused by the cohesion of their sides, for if we boil the pith for a short time, the bladders readily separate from each other. In pulpy fruits, or in those which have their cellular tissue in a loose dry state when ripe, the bladders may be readily separated from each other without boiling. It was formerly thought that cellular tissue might be compared to the air bubbles in a lather of soap and water;

fig. 3.



while by some it has been supposed to be formed by the doublings and foldings of a membrane in various directions. On both these suppositions, the partitions between the cells would be simple, and not composed of two membranes in a state of cohesion; but the facility with which, as has just been stated, the cellules may be separated, sufficiently disproves these opinions. But although the double nature of the partitions in cellular tissue may be often demonstrated, yet the cellules usually grow so firmly together, that their sides really form in their union but one membrane; and it will be hereafter seen that in many cases the partition between two cells is originally simple.

The bladders of cellular tissue are destitute of all perforation or visible pores, so that each is completely closed up from its neighbour, as far as we can see; although as they have the power of filtering fluids with rapidity, it is certain that they must abound in invisible pores, and that they are not impermeable, as if they were made of glass. An opinion different from this has been entertained by some observers, who have described and figured perforations of the membrane in various plants. Mirbel states that "the sides of the bladders are sometimes riddled full of holes (*fig.* 4.), the aperture of which does not exceed the $\frac{1}{300}$ of a millimetre (or of half a line); or are less frequently pierced with transverse slits, which are occasionally so numerous as to transform the bladders into a real articulated tissue, as in the pith of the Nelumbium (*fig.* 5.)." This statement is now well known to have been founded upon inaccurate observation; what the supposed pores really are has already been explained. (See p. 5.)

fig. 4.

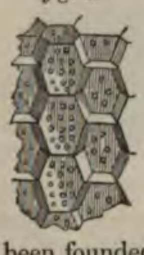
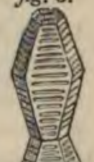


fig. 5.



With reference to this subject, it may be also observed, that the bladders often contain air-bubbles, which appear to have no direct means of escape, and that the limits of colour are always very accurately defined in petals, as, for instance, in the stripes of tulips and carnations, which could not be the case if cellular tissue were perforated by such holes as have been described; for in that case colours would necessarily run together.

Cellular tissue is generally transparent and colourless, or at most only slightly tinged with green. The brilliant colours of vegetable matter, the white, blue, yellow, scarlet, and other hues of the corolla, and the green of the bark and leaves, is not owing to any difference in the colour of the cells, but to colouring matter of different kinds which they contain. In the stem of the Garden Balsam (Impatiens Balsamina), a single cell is frequently red in the midst of others that are colourless. Examine the red bladder, and you will find it filled with a colouring matter of which the rest are destitute. The bright satiny appearance of many richly coloured flowers depends upon the colourless quality of the tissue. Thus, in Thysanotus fascicularis, the flowers of which are of a deep brilliant violet, with a remarkable satiny lustre, that appearance will be found to arise from each particular cell containing a single drop of coloured fluid, which gleams through the white shining membrane of the tissue, and produces the flickering lustre that is perceived. The cause of colour in plants will be spoken of hereafter in the second book.

The manner in which cellular tissue is generated and grows, would appear to differ in different plants. Amici says that the new tubes of Chara appear like young buds, from the points or axils of pre-existing tubes, an observation which has been confirmed by Slack. It has been stated by Mirbel that the same thing occurs in the case of Marchantia polymorpha. That learned botanist, in the course of his inquiries into the structure of this plant, found that in all cases one tube or utricle generated another externally, so that sometimes the membranes of newly-formed tissue had the appearance of knotted or branched cords. He satisfied himself that new parts are formed by the generative power of the first utricle, which spontaneously engenders on its surface others endowed with the same property. The amylaceous vesicles of malt in a state of fermentation manifestly produce new vesicles from their sides externally; and Turpin asserts that they also *contain* molecules, which are the rudiments of other cells.

This subject has lately engaged the attention of Professor

Mohl, whose researches show that this mode of generating cellular tissue is far from universal, as might indeed have already been suspected from what is known of the formation of pollen grains. It appears that in Confervæ the increase in number of the cells takes place by the internal division of the parent cells. In Conferva glomerata the last joint is always as long as those below it, only rather more slender. The branches grow at the upper lateral extremity of a joint or cell; each at first is a small protuberance, which is transformed into a lateral cylindrical excrescence containing chlorophyll (green colouring matter), and having its cavity in communication with that of the joint which bears it; as the branch lengthens, a contraction is observable at the line of insertion, which contraction is directed towards the interior of the cell, and chokes up the green matter, forming a sort of partition, pierced in the middle like a ring. This partition grows with the growth of the branch, and at last completely cuts off all communication between the first cell and its branch. Thus cut off, the latter lengthens by degrees, till it forms a very long cylindrical cell, which divides in just the same manner into two other cells, the terminal of which alone lengthens, to be again bisected in its turn.

Schleiden's ideas as to the origin of cells are still different from all these: see page 20.

The bladders develope, in some cases, with great rapidity. I have seen Lupinus polyphyllus grow in length at the rate of an inch and a half a day. The leaf of Urania speciosa has been found by Mulder to lengthen at the rate of from one and a half to three and a half lines per hour, and even as much as from four to five inches per day. But the most remarkable instances of this sort are to be found in the mushroom tribe, which in all cases develope with surprising rapidity. It is stated by Junghuns, that he has known the Bovista giganteum, in damp warm weather, grow in a single night from the size of a mere point to that of a huge gourd. We are not further informed of the dimensions of this specimen; but supposing its cellules to be not less than the $\frac{1}{200}$ of an inch in diameter, and it is probable they are nearer the $\frac{1}{400}$, it may be estimated to have consisted, when full grown, of about

47,000,000,000 cellules; so that, supposing it to have gained its size in the course of twelve hours, its bladders must have developed at the rate of near 4,000,000,000 per hour, or of more than sixty-six millions in a minute.

Cellular tissue grows for a long time after its generation, and hence the bulk of a given part may be much increased without the addition of any new elementary organs. Link states that in the branch of a Pelargonium cucullatum about 1 line in diameter, he found the larger cells $\frac{1}{21}$ of a line broad, which, in an older branch of the same plant, 2 lines in diameter, the larger cells were $\frac{1}{10}$ of a line broad; hence it was evident that the growth of the branch depended upon the growth of the individual cells.

The bladders of cellular tissue are always very small, but are exceedingly variable in size. The largest are generally found in the gourd tribe (Cucurbitaceæ), or in pith, or in aquatic plants; and of these some are as much as the $\frac{1}{30}$ of an inch in diameter; the ordinary size is about the $\frac{1}{400}$ or the $\frac{1}{500}$, and they are sometimes not more than the $\frac{1}{1000}$. Kieser has computed that in the garden pink more than 5100 are contained in half a cubic line.

Cellular tissue is found in two essentially different states, the *membranous* and the *fibrous*.

MEMBRANOUS CELLULAR TISSUE is that in which the sides consist of membrane only, without any trace of fibre; it is the most common, and was, till lately, supposed to be the only kind that exists. This sort of tissue is to be considered the basis of vegetable structure, and the only form indispensable to a plant. Many plants consist of nothing else; and in no case is it ever absent. It constitutes the whole of Mosses, Algæ and Lichens; it forms all the pulpy parts, the parenchyma of leaves, the pith, medullary rays, and principal part of the bark in the stem of Exogens, the soft substance of the stem of Endogens, the delicate membranes of flowers and their appendages, and both the hard and soft parts of fruits and seeds.

It appears that the spheroid is the figure which should be considered normal or typical in this kind of tissue; for that is the form in which bladders are always found when they are generated separately, without exercising any pressure upon each other; as, for example, is visible in the leaf of the white lily, and in the pulp of the strawberry or of other soft fruits, or in the dry berry of the Jujube. All other forms are considered to be caused by the compression or extension of such spheroids.

When a mass of spheroidal bladders is pressed together equally in all directions, rhomboidal dodecahedrons are produced, which, if cut across, exhibit the appearance of hexagons. (Plate I. fig. 12.) This is the state in which the tissue is found in the pith of all plants; and the rice paper, sold in the shops for making artificial flowers, and for drawing upon, which is really the pith of a Chinese plant, is an excellent illustration of it. If the force of extension or compression be greater in one direction than another, a variety of forms is produced, of which the following are the most worth noticing: —

1. The *oblong;* in the stem of Orchis latifolia, and in the inside of many leaves. (Plate I. fig. 9.)

2. The *lobed* (Plate I. fig. 2. *f*); in the inside of the leaf of Nuphar luteum, Lilium candidum, Vicia Faba, &c.: in this form of cellular tissue the vesicles are sometimes oblong with a sort of leg or projecting lobe towards one end; and sometimes irregularly triangular, with the sides pressed in and the angles truncated. They are well represented in the plates of Adolphe Brongniart's memoir upon the organization of leaves, in the *Annales des Sciences*, vol. xxi.

3. The *square;* in the cuticle of some leaves, in the bark of many herbaceous plants, and frequently in pith. (Plate I. fig. 13.)

4. The *prismatical;* in some pith, in liber, and in the vicinity of vessels of any sort. (Plate I. fig. 6.)

5. The *cylindrical* (Plate I. fig. 8. *a*); in Chara; this has been seen by Amici so large, that a single vesicle measured four inches in length and one third of a line in diameter. (*Ann. des Sciences*, vol. ii. p. 246.)

6. The *fusiform* or the oblong pointed at each end; in the membrane that surrounds the seed of a Gourd. (Plate I. fig. 5.)

7. The *muriform;* in the medullary rays. This consists of

prismatical bladders compressed between woody tissue or vessels, with their principal diameter horizontal, and in the direction of the radii of the stem. It is so arranged that when viewed laterally it resembles the bricks in a wall; whence its name. (Plate I. fig. 7.)

8. The *compressed;* in the cuticle of all plants. Here the bladders are often so compressed as to appear to be only a single membrane. (Plate I. fig. 2. *a;* Plate III. fig. 3, 4, &c.)

9. The *sinuous;* in the cuticle, and also sometimes beneath it, as in the leaf of Lilium candidum. (Plate III. fig. 5.)

10. The *stellated;* where the cells are so deeply lobed at the angles as to leave open passages between them, as in the stem of Eriophorum vaginatum. Plate III. fig. 2. is an approach to this structure.

11. The *tabular;* as in the epiphlæum of many plants.

Cellular tissue is frequently called *Parenchyma.* Professor Link distinguishes *Parenchyma* from *Prosenchyma;* referring to the former all tissue in which the bladders (Plate I. fig. 1, 3. 6, 7, &c.) have truncated extremities; and to the latter, forms of tissue in which the bladders taper to each end, and, consequently, overlap each other at their extremities.

Meyen has *Merenchyma,* for ellipsoidal and spheroidal cells; *Parenchyma* for angular cells; and *Prosenchyma* as above described.

FIBRO-CELLULAR TISSUE is that in which the sides are composed either of membrane and fibre together, or of fibre only.

It is only lately that this kind has been recognised. The first observation with which I am acquainted is that of Moldenhauer, who, in 1779, described the leaves of Sphagnum as marked by fibres twisted spirally. (*Fig.* 3. *a,* p. 9.) In November, 1827, I described the tissue of Maurandya Barclayana as consisting of bladders formed of spiral threads crossing each other, interlaced from the base to the apex, and connected by a membrane. A few other solitary cases of this kinds of tissue had subsequently been observed when the investigations of a modern anatomist suddenly threw an entirely new light upon the subject.

Instead of being very rare, cellular tissue of this kind appears to be found in various parts; it has been already mentioned as existing in the leaves of Sphagnum; it is also found in the pith of Rubus odoratus. I originally discovered it in the parenchyma of the leaves of Oncidium altissimum, and in the coat of various seeds. Mr. Griffith has detected it abundantly in the aërial roots of Orchidaceous plants, where in fact it is extremely common in numerous species, and Purkinje has shown, by a series of excellent observations and drawings, that it constitutes the lining of the valves of almost all anthers. The forms under which it exists in these parts are far more various than those of membranous cellular tissue. The principal varieties are these:—

A. *Membrane and Fibre combined.*

1. Fibres twisted spirally, adhering to a spheroidal or angular membrane, and often anastomosing irregularly, without the spires touching each other. (Plate I. fig. 12.) This is what is found in Oncidium altissimum leaves, in the aerial roots of some Orchidaceous plants, in the lining of many anthers, and is what Mohl has figured (*Ueber die Poren, &c.* tab. i. fig. 9.), from the pith of Rubus odoratus. It approaches very nearly to the nature of spiral vessels, hereafter to be described, and appears only to be distinguishable by the spires of the fibres not being in contact, being incapable of unrolling, having no elasticity or tenacity; and by the bladders not being cylindrical and tapering to each end, but spheroidal. It is easily examinable in Pleurothallis ruscifolia, and forms upon the side of the cells elevations which give them a beautifully pitted appearance when cut across. In the subcutaneous parenchyma of the leaves of this plant the fibres of one cell are placed exactly opposite those of the next cell, so that sections of the walls exhibit double depressions and elevations all along the line, so regular that, unless a very good microscope is used, they appear to form open passages from one cell to the other.

2. Fibres crossing each other spirally, and forming a reticulated appearance by their anastomosing within oblong blad-

ders. Of this nature are the reticulated cells of the seed-coat of Maurandya Barclayana, Wightia gigantea, and the like. (Plate I. fig. 11.)

3. Fibres running spirally close together, except at certain places where they separate and leave between them small spaces, which appear like dots.

4. Fibres running spirally, but completely grown together, except at certain spaces where they separate and leave small dot-like spaces. This and the last have been noticed by Mr. Valentine in Orchidaceous plants, and have been extremely well figured by Slack. (*Trans. Soc. Arts*, vol. xlix. *t.* 6. *f.* 5, 6.)

5. Fibres running straight along the sides of truncated cylindrical cells in the anthers of Richardia africana (Calla æthiopica) and many other plants. (Plate I. fig. 13.)

6. Fibres running transversely in parallel lines round three of the sides of prismatical right-angled cells, in the anthers of Nymphæaceæ, &c.

7. Fibres very short, attached to the sides of cells of various figures, to which they give a sort of toothed appearance, as in the anther of Phlomis fruticosa and other Labiatæ. (Plate I. fig. 15.)

The last three were first noticed by Purkinje.

8. The fibre twisted spirally, in the membranous tubes that form the *elaters* of Jungermannia, apparently constitutes another form of tissue of this order (Plate I. fig. 17.), and has recently been found by Corda among Fungi in the genus Trichia.

B. *Fibre without Membrane.*

It is not improbable that this form is always in the beginning of its growth composed of membrane. Mirbel has shown that the curious cells which line the anther of the common gourd are continuous membranes till just before the expansion of the flower, when they very suddenly enlarge, and their sides divide into narrow ribands or threads, curved in almost elliptical rings which adhere to the shell of the anther by one end; these rings are placed parallel with each other in each cell, to which they give an appearance like that of a little gallery with two rows of pilasters, the connecting arches of which remain after the destruction of the roof and walls. According to the observations of Dr. Schleiden, the formation of fibre never takes place independently of membrane, but occurs in the interior of cells, whose membrane was originally quite simple. He regards Corda's statements to the contrary (*Ueber Spiralfaserzellen*, 7. and 8.), as formed upon imperfect observations. He says that cells always attain their full size before the fibre appears, and he regards its formation as a part of the process of lignification. In the beginning he states that each cell is filled with starch, rarely with mucus or gum. By degrees the starch is always converted into the latter; this becomes changed, and, as it would seem, always from without inwards, into jelly. This jelly changes at its surface into a spiral fibre of variable width, which either does or does not adhere to the sides of the cells, and which may be supposed to owe its spiral direction to the course taken by a current setting between the side of the cell and the central mass of jelly.

The following are the more important varieties: —

1. Spiral fibres repressed by mucus, but having sufficient elasticity to uncoil when the mucus is dissolved, and then breaking up into rings. (Plate I. fig. 16.) These are what are found in the seed-coat of Collomia linearis. They approach spiral vessels so very nearly, that when I originally discovered them I mistook them for such. They are known by their depressed figure when at rest, by the want of an inclosing membrane, and by their brittleness when uncoiled.

2. Fibres short, straight, and radiating, so as to form little starlike appearances, found in the lining of the anthers of Polygala Chamæbuxus, &c. by Purkinje. (Plate I. fig. 19.)

3. Fibres originating in a circle, curving upwards into a sort of dome, and uniting at the summit, observed by the same anatomist in the anthers of Veronica perfoliata, &c.

4. Fibres standing in rows, each distinct from its neighbour, and having its point hooked, so that the whole has some resemblance to the teeth of a currycomb, in the anthers of Campanula; first noticed by Purkinje. (Plate I. fig. 18.)

5. Fibres forming distinct arches, as seen in the anthers of Linaria cymbalaria, &c. by Purkinje. (Plate I. fig. 4.) *

In the centre of some of the bladders of the cellular tissue of many plants there is a roundish nucleus, apparently consisting of granular matter, the nature of which is unknown. It was originally remarked by Francis Bauer, in the vesicles of the stigma of Phaius Tankervilliæ. A few other vegetable anatomists subsequently noticed its existence; and Brown, in his Memoir on the mode of impregnation in Orchidaceæ and Asclepiadaceæ, has made it the subject of more extended observation. According to this botanist, such nuclei not only occasionally appear on the cuticle of some plants (Plate III. fig. 9.), in the pubescence of Cypripedium and others, and in the internal tissue of the leaves, but also in the cells of the ovule before impregnation. It would seem that Brown considers stomates to be formed by the juxtaposition of two of these nuclei. (*See also Slack, in the Trans. Soc. Arts*, xlix.)

Dr. Schleiden has published some extremely interesting observations upon this body, which he regards as a universal elementary organ, and calls *Cytoblast.*† According to this observer, the *form* varies from oval to lenticular and round, the *colour* from yellowish to a silvery white, and changing to pale yellow up to darkest brown upon the application of iodine: in *size* it varies between $\frac{1}{2200}$ of a Paris inch in diameter, in Fritillaria pyrenaica, where it attains its largest size, and $\frac{1}{10000}$ in the embryonal end of the pollen tube of Linum pallescens. In structure it is usually granular; in consistence it varies between extreme softness and such a degree of toughness, as enables it to resist the pressure of the compressorium without altering its form. In the interior of the Cytoblast, or sunk in its surface, is a small, well-defined body, which, to judge from its shadow, represents a thick ring or a thick-sided hollow spherule: there is generally but one such spherule to each Cytoblast, but occasionally there are two or even three. The spherule varies in size from half the diameter of the Cytoblast to a point too small to be measured; and Dr. Schleiden has ascertained that this minute body is formed earlier than the Cytoblast itself. It is sometimes darker, sometimes clearer than the rest of the Cytoblast; and is usually of a firmer consistence, remaining well defined when the latter is crushed by pressure into amorphous mucus.

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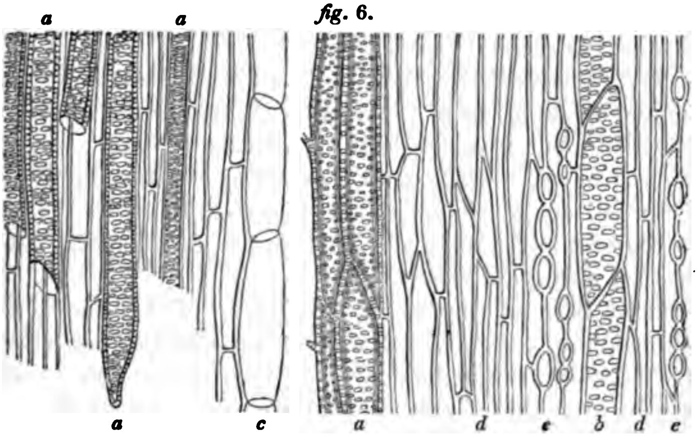
* According to the last mentioned author, the fibres themselves are generally tubular, and either perfectly round or somewhat compressed, or even three or four sided. He considers it proved that they are hollow, by their appearance when compressed, by their occasionally containing bubbles of air, and by the difference between their state when dried and when recent.

† I regret very much that my imperfect acquaintance with the German language is insufficient to enable me to give the valuable observations of this excellent observer more in detail.

If the gum which is found in the youngest albumen of a plant be examined, it will be found turbid with molecules of extreme minuteness. Of these some acquire a larger size and a more definite outline than others, and by degrees Cytoblasts appear, which seem to be a granular coagulation round each molecule. As soon as the Cytoblast has attained its full size, there appears upon it a fine transparent vesicle; this is a young cell, which at first represents a very flat segment of a sphere whose flat side is formed of the Cytoblast and convex side of the young vesicle, which is fixed upon it like the half of an hour-glass (*wie ein Uhrglas auf einer Uhr*). The space lying between the convexity of the vesicle and the Cytoblast is as clear and transparent as water, and is apparently filled with an aqueous fluid. If these young cells are isolated, we may, by shaking the field of the microscope, wash the mucous molecules almost clean; but they cannot be long observed, because they dissolve in distilled water in a few minutes, and leave nothing but the Cytoblast behind. The vesicles continue to swell out, and their lining becomes formed of jelly, with the exception of the Cytoblast, which soon becomes a part of their wall: the cell keeps increasing in size, till at last the Cytoblast is only a minute body imbedded in the side of the cavity, or sometimes loose in the cavity. It is, however, in time absorbed, and it is only after its absorption has occurred that, as Schleiden believes, the process of depositing secondary layers begins. The Cytoblast appears, however, sometimes to have a permanent existence, as in the pollen of Larix europæa, and in those hairs in which a circulation of the sap is observable. In those Schleiden has remarked (and my own observations coincide with his) that all the currents proceed from the Cytoblast and return to it.

SECT. II. *Of Pitted Tissue*, or *Bothrenchyma.**

fig. 6.



THIS, which has had a variety of names, (*Tubes poreux, Vaisseaux en chapelet, Tubes corpusculifères*, Vasiform Tissue, Dotted Ducts,) consists of tubes, often of considerable size, appearing when viewed by transmitted light as if riddled full of holes. Upon a more accurate inspection, however, it is found to receive that appearance from its sides being filled with little pits sunk in the thickness of the lining. (See Plate II. fig. 2.) Of this there are two kinds.

1. *Articulated Bothrenchyma.*—This is very common in wood. The holes which are so evident to the naked eye, in a transverse section of the oak or the vine, are its mouths; and the large openings in the ends of the woody bundles of Monocotyledonous stems, as in the Cane, are also almost always caused by the section of it. The stems of Arundo Donax, or of any larger grass, is an excellent subject for seeking it in; it can be readily extracted from them when boiled. It is composed of truncated cylinders, placed one upon the other, and so forming a long cylinder, which be-

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* Βοθρος, a little pit.

comes a tube, open from end to end when the partitions between the cells are absorbed. The cylinders in some plants, as in Phytocrene, are regular in size, and easily separate from each other, as has been observed by Griffith; in other cases, and this is the most common case, their ends are oblique and produce the appearance of bands when they come in contact (*fig.* 6. *b.*): hence they have been looked upon as a modification of the spiral vessel.

2. *Continuous Bothrenchyma.*—This (*fig.* 6. *a a a*) forms the *Vasa spiroidea porosa* of Link, and is still less of the nature of vascular tissue than the last. It consists of long, slender, uninterrupted, pitted tubes, resembling Pleurenchyma in form, but not tough, nor collected into solid bundles. This is common in the roots of plants, and is often found in connection with spiral vessels.

It has been said by Bischoff that tissue of this kind is an alteration of a spiral vessel, whose fibre is broken into short pieces, which stick to the sides of the tube and cause the pitted appearance. Mr. Slack adopted this idea: he considered them to be transparent spaces in the sides of the cells, and caused by the separation, at intervals, of a spiral fibre whose convolutions are partially and firmly united in the spaces between the dots; and he represents a case of vasiform tissue from Hippuris in illustration of his position. But I have sought in vain for any proof of the correctness of these views. On the contrary, it is probable that the functions of Taphrenchyma are to convey fluid, which is an additional reason for regarding it entirely distinct from vascular tissue.

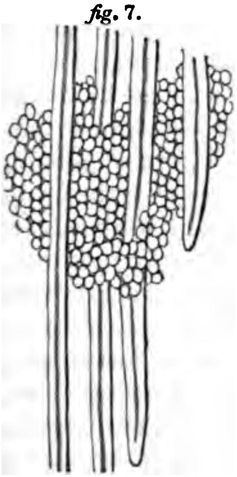
The granular woody tissue of former editions of this work I now regard as a form of continuous Bothrenchyma. Renewed observation with better instruments satisfy me that the marks on the sides of the tubes of Cycadaceæ, taken by Adolphe Brongniart for pores, and by myself for granules, are neither the one nor the other, but short oblique furrows in the lining of the tubes.

SECT. III. *Of Woody Tissue*, or *Pleurenchyma*.

THIS, which Meyen calls *Pleurenchyma*, consists of very slender, tough, transparent, membranous tubes, tapering acutely to each end, lying in bundles, and, like the cellular tissue, generally having no direct communication with each other, except by invisible pores. Slack states, that they are often met with open at their extremities; "which probably arises either from the membrane being obliterated where it was applied to another fibre, or ruptured by the presence of an adjoining tube, as we sometimes find the conical extremity of another tube inserted into the aperture."

Many vegetable anatomists consider it a mere form of cellular tissue, in an elongated state. However true this may be in theory, woody tissue may be known by its toughness and extremely attenuated character. The distinction between cellular and woody tissue is particularly well seen in the long club-shaped aërial radicle of Rhizophora Candelaria. It there consists of large, very long, transparent tubes, lying imbedded in fine brownish granular matter, which is minute cellular tissue (*fig.* 7.)

fig. 7.



Usually it has no markings upon its surface, except occasionally a particle or two of greenish matter in its inside; but sometimes it is covered with spots that have been mistaken for pores, and which give it a peculiar character (Plate II. fig. 3. 5. and 20.); and I have remarked an instance, in Oncidium altissimum, of its having tubercles on its surface. It often contains amylaceous granules in abundance. Generally, while cellular tissue is brittle, and has little or no cohesion, woody tissue has great tenacity and strength; whence its capability of being manufactured into linen. Every thing prepared from flax, hemp, and the like, is composed of woody tissue; but cotton, which is cellular tissue, bears no comparison as to strength, with either flax or hemp.

Alphonse De Candolle gives the following as the result obtained by Labillardière, as to the relative strength of different organic fibres. He found that, in suspending weights to threads of the same diameter,

Silk supported a weight equal to . .	34
New Zealand flax, ...	$23\frac{4}{5}$
Hemp, ...	$16\frac{1}{5}$
Flax, ...	$11\frac{3}{4}$
Pita flax (Agave Americana), . . .	7

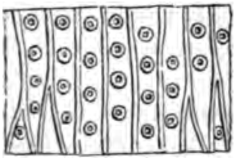
That even the most delicate woody tissue consists of tubes, may be readily seen by examining it with a high magnifying power, and also by the occasional detection of particles of greenish matter in its inside. A very different opinion has nevertheless been held by some physiologists, who have thought that the woody tissue is capable of endless divisibility. " When," says Duhamel, " I have examined under the microscope one of the principal fibres of a pear tree, it seemed to me to consist of a bundle of yet finer fibres; and when I have detached one of those fibres, and submitted it to a more powerful magnifying power than the first, it has still appeared to be formed of a great number of yet more delicate fibres." (*Physique des Arbres*, i. 57.) To this opinion Du Petit Thouars assents, conceiving the tenuity of a fibre to be infinite, as well as its extensibility. (*Essais sur la Végétation*, p. 150.) These views have doubtless arisen from the use of very imperfect microscopes; under low powers of which such appearances as Duhamel describes are visible; but with modern glasses, and after maceration, each particular tube can be separated with the greatest facility. Their diameter is often very much less than that of the finest human hair; the tubes of hemp, for example, when completely separated, are nearly six times smaller. It must, however, be observed, that the fibres of this plant, as used in linen-making, are by no means in a state of final separation, each of the finest that meets the naked eye being in reality a bundle of tubes. While some do not exceed $\frac{1}{3000}$ of an inch in diameter, others have a diameter as considerable as that of ordinary cellular tissue itself; in Coniferæ the tubes are often $\frac{1}{200}$ or $\frac{1}{300}$, and in the Lime they average about $\frac{1}{130}$. Link states (*Elementa*, p. 85.) that they are very large in trees of hot countries. The sides of woody tissue become thickened, as they advance in age, by the successive deposits of layer after layer in their interior (see *fig.* 1.); this is particularly observable in the liber, and hence, perhaps, the reason why the toughest kinds of fibre are obtained from that part.

There are two distinct kinds of Pleurenchyma:—

1. That in which the walls are not occupied with either granules or glands sticking to them, or in which the former are of very rare occurrence. (*Fig.* 7.) This is the finest and the commonest of all; and is also the most genuine state of woody tissue.

2. The second kind of woody tissue is the *glandular.* This has hitherto been examined chiefly in Coniferæ, in which it uniformly occurs. Its dimensions are more considerable than that of the last-mentioned form, and it has been described as perforated with pores. The markings of the tubes are vesicular, and usually transparent, with a darkened centre (Plate II. fig. 3.), which last is what has been described as a pore, the vesicle itself being considered a thickened rim.

fig. 8.



Kieser figures the glands as pores in Pinewood (*fig.* 8.), in Ephedra, and other cases. They may be most conveniently found by examining with a microscope a thin shaving of common Pinewood (Pinus Strobus), when they will be seen in the form of transparent globules, having a dark centre, and placed upon the walls of the pleurenchyma.

The structure of coniferous glands has of late attracted the attention of many anatomists, and, at last, Professor Mohl seems to have discovered their real nature. He states them to be circular spaces, thinner than the rest of the tube, and placed opposite each other, so that when the walls are examined by transmitted light they appear more transparent than the rest of the tube. A plan of this structure is given in a cross section of two tubes in Plate II. fig. 4., where *a a* represent depressions in the centre of the elevation, which depression is supposed to cause the appearance of a central pore. With patience sections may be obtained so as to show the glands in profile, and then they are seen to project considerably above the wall of the tube. In a specimen of Pinus Strobus I have found them surrounded with an irregular elevated rim, as at Plate II. fig. 7. and 8., as if the lining of the tube was growing over them. It is not at all uncommon to find them in what may be supposed a nascent state, merely looking like tumours, with a pore in the middle, as is shown at Plate II. fig. 5.

If the disks of coniferous wood are examined with a good eighth of an inch object glass, and a low ocular, they will be distinctly seen marked with concentric circles as represented at Plate II. fig. 6. The highest oculars with a lower objective will not separate the circular lines. M. Valentin, who first noticed them (*Repertorium*, vol. i. t. i.), considers them to be the projecting edges of numerous layers of woody matter concentrically deposited round a space which they gradually close up, except a narrow opening into an air chamber, the layer next the centre being the youngest. I have not succeeded in obtaining any section which will show this structure.

It has been imagined that this glandular Pleurenchyma is confined to Gymnosperms, but Dr. Brown long since remarked it in Tasmannia, and Mr. Griffith finds it common in aromatic trees. At Plate II. fig. 20. is a view of it as I see it in Sphærostema.

The nature of the disks has been examined by M. Guillemin, who, in a paper laid before the Academy of Sciences, Dec. 19, 1836, considers them to be tumours, and calls them *Œdemata.* He supposes them to be flattened vesicles, the central circle being either a pore or minute cell; and he imagines them to be filled with a colourless volatile oil, which changes to turpentine when it has been exuded from the central luminous point. He also adverts to the existence of similar appearances in aromatic woods, especially Drimys chilensis, but says they are not to be confounded with *Œdemata.* (*Comptes Rendus*, iii. 761.)

Pleurenchyma constitutes a considerable proportion of the ligneous part of all plants; it is abundant in liber, and forms the principal part of the veins of leaves, to which it gives stiffness and tenacity.

SECT. IV. *Of Vascular Tissue, or Trachenchyma.*

THIS consists of simple membranous tubes tapering to each end, but often ending abruptly, either having a fibre generated spirally in the inside, or having their walls marked by transverse bars arranged more or less in a spiral direction.

Such appears to me to be the most accurate mode of describing this kind of tissue, upon the exact nature of which anatomists are, however, much divided in opinion; some believing that the fibre coheres independently of any membrane, others doubting or denying the mode in which the vessels terminate; some describing the vessels as ramifying; and a fourth class ascribing to them pores and fissures, as we have already seen has been done in cellular and woody tissue. It will be most convenient to consider all these points separately, along with the varieties into which vascular tissue passes.

There are two principal kinds of vascular tissue; viz. spiral vessels (Plate II. fig. 3. b. 9. 11.), and ducts (Plate II. fig. 12. c. *f.* 15, 16. 18. 20.)

SPIRAL VESSELS or TRACHEÆ are membranous tubes with conical extremities; their inside being occupied by a fibre twisted spirally, and capable of unrolling with elasticity. To the eye they, when at rest, look like a wire twisted round a cylinder that is afterwards removed. For the purpose of finding them for examination, the stalk of a strawberry leaf, or a young shoot of the Cornus alba (common dogwood) may be conveniently used; in these they may be readily detected by gently pulling the specimen asunder, when they unroll, and appear to the naked eye like a fine cobweb.

Very different opinions have been entertained as to the exact structure of spiral vessels. They have been considered to be composed of a fibre only, twisted spirally, without any connecting membrane; or to have their coils connected by an extremely thin membrane, which is destroyed when the vessel unrolls; or to consist of a fibre rolled round a membranous cylinder; or even, and this was Malpighi's idea, to be formed by a spiral fibre kept together as a tube by interlaced fibres. Again, the fibre itself has been by some thought to be a flat strap, by others a tube, and by a third class of observers a kind of gutter formed by a strap having its edges turned a little inwards. Finally, the mode in which they terminate, has been asserted to be a continuation of cellular tissue.

With regard to the presence of an external membrane within which the spiral fibre is developed, an examination of it externally, by means of longitudinal sections of the surrounding parts, is scarcely sufficient to settle that point. The best mode of examination is to separate a vessel entire from the rest of the tissue, which may be done by boiling the subject, and then tearing it in pieces with the points of needles or any delicate sharp instrument: the real structure will then become much more apparent than if the vessel be viewed in connection with the surrounding tissue. From some beautiful preparations of this kind by Mr. Valentine and Mr. Griffith, it appears that the membrane is external: in the root of the Hyacinth, for example, the coils of the spiral vessel touch each other, except towards its extremities; there they gradually separate, and it is then easy to see that the spiral fibre does not project beyond the membrane, but is bounded externally by the latter, which would not be the case if the membrane were internal: a representation of such a vessel is given at Plate II. fig. 9. Another argument as to the membrane being external may be taken from the manifest analogy that a spiral vessel bears to that form of cellular tissue (p. 16.), in which a spiral fibre is generated *within* a cellule: it is probable that the origin of the fibre is the same in both cases, and that its position with regard to the membrane is also the same. Sections, moreover, may be obtained through the centre of spiral vessels, and then it is manifest that the fibre is internal, because it projects beyond the inside of the vessel, at every turn.

It is more difficult to determine whether the fibre is solid, or tubular, or flat like a strap; and Amici has even declared his belief that the question is not capable of solution with such optical instruments as are now in use. When magnified 500 times in diameter, a fibre appears to be transparent in the middle, and more or less opaque at the edges; a circumstance which has no doubt given rise to the idea that it is a strap or riband, with the edges either thickened, according to De Candolle, or rolled inwards, according to Mirbel. But it is also the property of a transparent cylinder to exhibit this appearance when viewed by transmitted light, as any one may satisfy himself by examining a bit of a thermometer tube. A better mode of judging is, perhaps, to be found in the way in which the fibre bends when the vessel is flattened. If it were a flat thread, there would be no convexity at the angle of flexure, but the external edge of the bend would be straight. The fibre, however, always maintains its roundness, whatever the degree of pressure that may be applied to it. (Plate II. fig. 10.) This I think conclusive as to the roundness of the fibre; but it does not determine the question of its being tubular or solid. Bischoff, who has investigated the nature of spiral vessels, asserts (*De verâ vasorum plantarum spiralium Structurâ et Functione Commentatio*, 1829), that it is solid, and this agrees with my own observations. But M. Girou de Buzareingues states that it is hollow and contains fluid, and he gives numerous excessively magnified figures to illustrate his statement. Hedwig also long since believed that, when coloured fluids rise in spiral vessels, he saw them follow the direction of the spires. This last fact may, however, be explained upon the supposition that they rise in the channels formed by the approximation of cylindrical fibres, and not in the fibres themselves; in which case there could be little doubt that the fibres are really solid; and I must declare that I can find no such appearances as those described by M. de Buzareingues.

The last-mentioned physiologist states, that the fibre often runs *between* two cylindrical tubes, so that there is not only an outer membrane, but an inner one also. He adds that the inner tube contains air, but that fluid is lodged in the space between the two tubes. These observations cannot be repeated, for the learned author on no occasion names the plants in which he has remarked these peculiarities of structure, which have hitherto escaped the most skilful vegetable anatomists.

Link contends, that the fibre, although simple at first, soon forks and forks again, and that the branches thus produced all follow the direction of the spire.

The termination of spiral vessels is, beyond all doubt, conical. This was stated by Nees von Essenbeck, in his *Handbuch der Botanik*, published in 1820; and in 1824 Dutrochet asserted, that they end in conical spires, the point of which becomes very acute; but one would not suppose, judging from the figure given by the latter writer, that he had seen the terminations very clearly. If the point of a spiral vessel in the Hyacinth (Plate II. fig. 9.) be examined, it will be seen that the end of the spiral fibre lies just within the acute point of the vessel, and that the spires become gradually more and more relaxed as they approach the extremity, as if their power of extension gradually diminished, and the membrane acquired its pointed figure by the diminution of elasticity and extensibility in the fibre. It is not, however, always in a distinct membrane that the spiral vessel ends. In Nepenthes the fibres terminate in a blunt cone, in which no membrane is discoverable. (Plate II. fig. 11.) *

A spiral vessel is formed by the convolutions either of a single spire, or of many, always turning in the same direction. In the first case it is called *simple*, in the latter *compound*. The simple is the most common. (Plate II. fig. 9.) Kieser finds from two to nine fibres in the Banana. De la Chesnaye as many as twenty-two in the same plant. There are four in Nepenthes (Plate II. fig. 11.), five in Liparis pendula. In general, compound spiral vessels are thought to be almost confined to Endogenous plants, where they are very common in certain families, especially Marantaceæ, Zingiberaceæ, and Musaceæ; but their existence in Nepenthes, and, according to Rudolphi, in Heracleum speciosum, renders it probable that future observations will show them to be not uncommon among Exogens also.

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* A singular change occurs in the appearance of the spiral vessels of Nepenthes, after long maceration in dilute nitric acid, or caustic potash: the extremities cease to be conical and spirally fibrous, but become little transparent oblong sacs, in which the spires of the fibres gradually lose themselves. This alteration, which is a very likely cause of deception, is perhaps owing to the extremities of the vessels being more soluble than the other part, the sac being composed of the confluent dissolved fibres. This is in some measure confirmed by the subsequent disappearance of all trace of fibres in any part of the vessels, under the influence of those powerful solvents.

In Coniferæ the spiral vessels have in some cases their spires very remote, and even have glands upon their membrane between the spires. Link speaks of a peculiar kind of spiral found in Coniferous plants "fibris tenuissimis distincta," and calls them *vasa spiralia fibrosa.*

In size, spiral vessels, like other kinds of tissue, are variable; they are generally very small in the petals and filaments. Mirbel states them to be sometimes as much as the 288th of an inch in diameter; Hedwig finds them, in some cases, not exceeding the 3000th; a very common size is the 1000th. According to the observations of Link, they may be found of extremely different size in one and the same bundle of tissue in the stem of Canna, the largest being $\frac{1}{300}$, the middle size $\frac{1}{960}$, and the smallest $\frac{1}{2000}$ of an inch in diameter.

An irritability of a curious kind has been noticed by Malpighi in the fibre of a spiral vessel. He says (*Anat.* p. 3.), that in herbaceous plants, and some trees, especially in the winter, a beautiful sight may be observed, by tearing gently asunder a portion of a branch or stem still green, so as to separate the coils of the spires. The fibre will be found to have a peristaltic motion, which lasts for a considerable time. An appearance of the same nature has been described by Don in the bark of Urtica nivea. These observations are, however, not conformable to the experience of others. De Candolle is of opinion that the motion seen by Malpighi is due to a hygrometrical quality combined with elasticity; and as spiral vessels do not exist in the bark of Urtica nivea, it seems that there is some inaccuracy in Don's remark.

The situation of spiral vessels is in that part of the axis of the stem surrounding the pith, and called the medullary sheath, and also in every part the tissue of which originates from it; such as the veins of leaves, and petals, and of all other modifications of leaves. It has been supposed that they are never found either in the bark, the wood, or the root; and this appears to be generally true. But there are exceptions to this: Mirbel and Amici have noticed their existence in roots; and Mr. Valentine and Mr. Griffith have both extracted them from the root of the Hyacinth; they do not, however, appear to have been hitherto seen in the roots of Exogens. I know of no instance of their existence in bark, except in Nepenthes, where they are found in prodigious quantities, not only between the alburnum and the liber, embedded in cellular tissue, as was first pointed out to me by Mr. Valentine, but also sparingly both in the bark and wood. They have been described by myself as forming part of the testa of the seed of Collomia, and Brown has described them as existing abundantly in that of Casuarina. In the former case, the tissue was rather the fibro-cellular, as has been already explained (p. 18.); in the latter, they are apparently of an intermediate nature between the fibro-cellular and the vascular; agreeing with the former in size, situation, and general appearance, but differing in being capable of unrolling. In the stem of Endogens, spiral vessels occur in the bundles of woody tissue that lie among its cellular substance; in the leaves of some plants of this description they are found in such abundance, that, according to De la Chesnaye, as quoted by De Candolle, they are collected in handfuls in some islands of the West Indies for tinder. The same author informs us that about a drachm and a half is yielded by every plantain, and that the fibres may be employed either in the manufacture of a sort of down, or may be spun into thread. In Coniferous plants they are few and very small, and in Flowerless plants they are for the most part altogether absent; the only exceptions being in Ferns and Lycopodiaceæ, orders occupying a sort of middle place between flowering and flowerless plants: in these they no doubt exist. My friend, Mr. Griffith, has succeeded in unrolling them in the young shoots of Lycopodium denticulatum, and Mr. Quekett in Diplagium seramporense.

Some have thought that the spiral vessels terminate in those little openings of the cuticle called stomates; but there does not seem to be any foundation for this opinion.

DUCTS (Plate II. fig. 12. and 15.) are membranous tubes, with conical or rounded extremities; their sides being marked with transverse lines, or rings, or bars, and being incapable of unrolling without breaking.

These approach so nearly to the spiral vessel that it is impossible to doubt their being a mere modification of it. Some writers confound all the forms under the common name of spiral vessels, but it is more convenient to consider them as distinct, not only on account of their peculiar appearances, but because they occupy a station in plants in which true spiral vessels are not often found; and it is therefore probable that their functions are different. They vary between the $\frac{1}{400}$ and the $\frac{1}{800}$ of an inch in diameter.

All the forms of the duct seem reducible to the following varieties: —

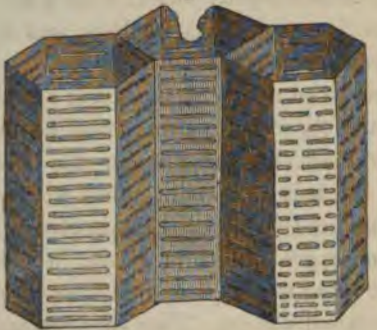
1. The *Closed* (Plate II. fig. 15.), which are absolutely the same as spiral vessels, except that they will not unroll.

2. The *Annular* (Plate II. fig. 12. *d*). These are well described by Bischoff as being formed of fibrous rings, placed at uncertain intervals; or, to speak more accurately, they, like spiral vessels, are formed of a spiral thread, but it is often broken, so as, in some parts, to separate into a number of distinct rings. These rings are included within a membranous tube, by which they are held together. Annular ducts are common in the soft parts of plants, especially in such as grow with much rapidity; in the Garden Balsam they are particularly abundant. They are among the largest kinds of vessels.

3. The *Reticulated* (Plate II. fig. 12. *f*). In these the spiral fibre, instead of separating into a number of distinct rings, is continuous in some places, and anastomoses in others, so as to form a sort of netted appearance. Vessels of this kind, like the last, are found in the stem of some herbaceous plants; as, for example, the Garden Balsam, in which they may be seen in a great variety of states.

4. The *Scalariform*, which are extremely abundant in Ferns. These are angular tubes, whose sides are marked by transverse bars that scarcely reach the angles. (*Fig.* 9.)

Fig. 9.



In all probability the spiral vessel is the type of all these; and the differences we perceive in them are owing to the various modes in which they are subjected to the force of developement. Thus the closed duct may be considered to be absolutely a spiral vessel, with little or no power of unrolling; the annular to be the same thing, but with the enveloping membrane growing more rapidly than the enclosed fibre, which is consequently broken into pieces that contract into rings. Reticulated ducts may in like manner be considered as spiral vessels, whose internal spire, instead of snapping into short lengths as the membrane extends, accommodates itself to the growth of the latter by separating its coils, which thus gain an irregular direction, and grow together at points of variable distance. I think this view of the nature of ducts was first taken by Mr. Solly. It is well illustrated by Slack in the paper already referred to, and it derives additional strength from the fact, which, I believe, has never before been mentioned, that ducts, common as they are in the Garden Balsam when full grown, are scarcely to be found in that plant in a young state.

Some anatomists have added to the varieties above enumerated, what they call strangulated vessels (*vaisseaux en chapelet* or *étranglés*, *corpuscula vermiformia*, *vasa moniliformia*). These are determined by Bischoff to be mere accidental forms, caused by their irregular compression, when growing in knots or parts that are subject to an interrupted kind of developement. They may be found figured in Mirbel's *Elémens*, tab. x. fig. 15.; and in Kieser, fig. 56. and 57.; but the best view of their origin and true nature is in Slack's plate, fig. 33., in the Transactions of the Society of Arts, before referred to. Link defines them to be short spiral vessels with attenuated extremities, and regards them, in his latest works, as young spiral vessels, or as the commencement of spiral vessels, which, instead of lengthening, grow together by their ends.

Vascular tissue always consists of tubes that are unbranched. They have been represented by Mirbel as ramifying in some cases: but this opinion has undoubtedly arisen from imperfect observation. When forming a series of vessels, the ends of the tubes overlay each other, as represented in Plate II. fig. 15.

Slack states that the membrane is often obliterated at the place where two vessels touch each other, and that transverse bars only remain under the form of a grating: this appearance is produced by the remains of the spiral fibre, several of whose convolutions are partially uncovered by the absorption of the enveloping membrane. It would hence appear that ducts open into each other at their points of contact.

SECT. V. *Of Laticiferous Tissue*, or *Cinenchyma.*

THE earlier anatomists were acquainted with the existence of milk vessels in many plants, but they gave no account of them sufficiently exact to distinguish them from other kinds of tissue, and, accordingly, they have been usually looked upon as forms of Pleurenchyma, or of Trachenchyma, or as intercellular cavities.

It was reserved for Prof. Schultz of Berlin to show the general existence of such vessels, and their real nature. The memoir upon this subject, in which his most recent views are stated, has not yet been published; but there is an abstract of it by M. Auguste de St. Hilaire in the *Annales des Sciences*, and upon this, and my own observations, the following account of them is founded.

Laticiferous tissue (*Vital vessels, Vasa opophora*) consists of branched anastomosing tubes, lying in no definite position with regard to other tissue, large and thick-sided when old, but so capillary and thin when young as hardly to be visible. The sides are not parallel as in other vessels, but often contracted and expanded at intervals, so that they may be described as partially closed up by strictures here and there: they are said to have a power of contraction, but there are no valves or dissepiments in their interior. The larger trunks Schultz calls *vasa expansa*, and the fine ramifications *vasa contracta.*

This kind of tissue has generally an undulatory direction (Plate II., fig. 19.). In their interior there is a quantity of granular matter, which sometimes fills them wholly, and sometimes is separated by empty spaces. Their average size is $\frac{1}{1100}$ of an inch. Their sides, although they thicken by the successive deposit of new matter, never offer any marks, or pits, or other interruptions of continuity.

It is obvious from these characters that cinenchyma is quite different from every other form of tissue. Its constant, irregular branching and anastomosing would alone distinguish it.

As such vessels lie in no definite direction with respect to the rest of the tissue, they have been generally overlooked, and are often very difficult to find, although always present in the greater part of flowering plants. M. Schultz recommends maceration for five or six days, as affording a ready means of separating them from the surrounding tissue. It is, however, easy to find them in the liber of the Fig, in the roots of Dandelion, Scorzonera, Lettuce, and other milky Cichoraceæ, or in any of the parts of Chelidonium.

They are placed in great abundance in the innermost layers of the liber, across the Parenchyma of foliaceous organs, in the bark of the root, in the pith, and probably in all other parts; but their station seems to vary in different species. Sometimes they accompany the spiral vessels, forming a part of the bundle of tissue to which those organs belong. From the interior parts they proceed by finer and finer ramifications until they enter the hairs of many plants, in which they form a plexus of excessively fine vessels.

In the lowest orders of plants, and in some others, they are wholly wanting. They are largest in plants having milky juice, and smallest in those whose juice is transparent.

Plate II. contains representations of several laticiferous vessels. Fig. 13. and 18. shows them in the capillary state in the hairs of plants. Fig. 16. shows them thin-sided and filled with latex. Fig. 17. represents them thick-sided and filled with latex. Fig. 19. shows them empty. At fig. 12. *a*, and *g*, they are seen parallel with the other tissue, filled with latex, and a little contracted at intervals.

SECT. VI. *Of spurious elementary Organs; such as Air Cells, Receptacles of Secretion, Glands, &c. &c.*

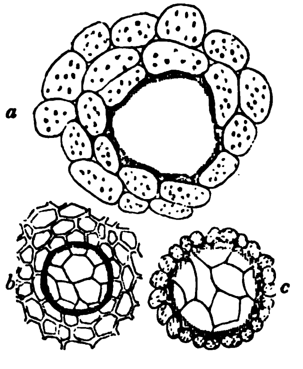
THE kinds of tissue now enumerated are all that have as yet been discovered in the fabric of a plant. There are, however, some other internal parts, which although not elementary, being themselves made up of some one or other of the forms of tissue already described, nevertheless have either been sometimes considered as elementary, or at least are not referable to the appendages of the axis, and can be treated of more conveniently in this place than elsewhere. These are, 1. *Intercellular passages*; 2. *Receptacles of secretion*; 3. *Air cells*; 4. *Raphides.*

1. Of Intercellular Passages.

As the elementary organs are all modifications of either the spherical or cylindrical figure, it must necessarily happen that when they are pressed together, spaces between them will remain, which will be more or less considerable in proportion as the tissue preserves in a greater or less degree the cylindrical or spherical form. When the pressure has been very uniform, as in the case of the tissue of the cuticle, and in many states of cellular substance, or when elementary mucus holds the tissue together completely, no spaces will exist. When they do exist, they are called *Intercellular passages.* They necessarily follow the course of the tissue, being horizontal, vertical, or oblique, according to the direction of the angles of the tissue by which they are formed. Their size varies according to the size of the tissue and the quantity of sap. In plants of a dry nature, they are frequently so small as to be scarcely discoverable; while in succulent plants they are so large as to approach the size of cells, as in the stem of Tropæolum majus. They are remarkably large in the horizontal partitions which separate the air cells of water plants. In Limnocharis Plumieri they exist in the form of little holes at every angle of the hexagons of which the partitions in that plant consist; and are, no doubt, there intended as a beautiful contrivance to enable air to pass freely from one cavity to another.

2. Of Receptacles of Secretion.

Fig. 10.



But it frequently occurs that the simple intercellular passages are dilated by the secretions they receive, and either increase unusually in size, or rupture the coats of the neighbouring tissue; by which means cavities are formed, replete with the sap altered to the state which is peculiar to the particular species of tree producing it. Cavities of this nature are often called *vasa propria.* To this class also are to be referred the *turpentine vessels* of Grew; the *réservoirs accidentels* of De Candolle; and also the *réservoirs* *en cæcum* of the latter, which are the clavate vessels of oil found in the coat of the fruit of Umbelliferæ, and which are commonly called *vittæ*. Although the receptacles of secretion have no proper coat, yet they are so surrounded by cellular tissue, that a lining or wall is formed, of perfect regularity and symmetry. The tissue of this lining is generally much smaller than that of the neighbouring parts. When filled with a fluid having a different refractive power from that of the surrounding parts, they give a semitransparent dotted appearance to the organs in which they occur, as may be seen by holding up the leaf of an orange tree against the light.

While, however, many kinds of receptacles of secretion are mere cavities in the tissue, others are little nuclei of cells, as in the Dictamnus (*fig.* 10. *c*). These are of the nature of glands, and are called internal glands by Meyen.

Numerous modifications of these parts have been described by the German anatomists, especially by the last-mentioned author, but they only relate to the refinements of the subject. In figure, the receptacles are extremely variable, most commonly round, as in the leaves of the Orange and of all Myrtaceæ, where they are called *crypta*, or *glandulæ impressæ*, or *réservoirs vesiculaires*, or *glandes vesiculaires*, or *receptacles of oil*. In the Pistacia Terebinthus the receptacles are tubular; in Coniferæ they are very irregular in figure, and even position, chiefly forming large hollow cylindrical spaces in the bark. Those in the rind of the orange and lemon are little oblong or spherical cysts; their construction, which is easily examined, gives an accurate idea of that of all the rest.

3. Of Air Cells.

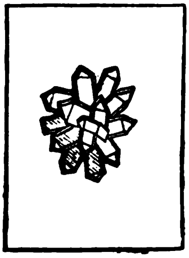
Besides the common intercellular passages, and the receptacles now described, there is another and a very remarkable sort of cavity among the tissue of plants. This is the *air cell*; the *lacuna* of Link. Like the receptacles of secretion, the air cells have no proper membrane of their own, but are built up of tissue; and this sometimes takes place with a wonderful degree of uniformity and beauty. Each cell is often constructed so exactly like its neighbour, that it is impossible to regard it as a mere accidental distension of the tissue: on the contrary, air cells are, in those plants to the existence of which they are necessary, evidently formed upon a plan which is uniform in the species, and which has been wisely contrived by Providence in the manner best adapted to the purpose for which they are destined.

They differ from receptacles of secretion in containing air only, and not the proper juice of the plant; a peculiarity which is provided for by a curious contrivance of Nature. In receptacles, the orifices of the intercellular passages through which the fluid that is to be deposited drains, are all open; but, to prevent any discharge of fluid into the air cells, the orifices of all the intercellular passages that would otherwise open into them are closed up, except in the partitions that divide them from each other.

Air cells are very variable in size, figure, and arrangement. In the stem of the Rush (Juncus articulatus), they consist of a number of tubular cavities placed one above the other, and separated by membranous partitions composed of a combination of minute bladders; in some aquatic plants they are very small, as in Butomus umbellatus. In form they are either cylindrical, or they assume the figure of the bladders by which they are formed, as in Limnocharis Plumieri (Plate III. fig. 1. and 2.), in which the structure of the air cells and their coats forms one of the most beautiful of microscopical objects. In the green parenchymatous parts of plants, such as the leaf, the cortical integument, &c., where they always abound, they are irregular spaces among the tissue, communicating freely with each other. They are represented in Plate I. fig. 2.

The inner surface of the air cells, when those parts are essential to the life of a plant, is smooth and uniform; but in grasses, umbelliferous plants, and others where air cells are not essential, they seem to be caused by the growth of the stem being more rapid than the formation of the air cells; so that the tissue is torn asunder into cavities of an irregular figure and surface. Kieser was the first to observe that in many plants in which the air cells of the stem are regularly separated by partitions, the intercellular passages of the bladders forming the partitions are sometimes left open, so that a free communication is maintained between all the tiers of air cells.

4. Of Raphides.



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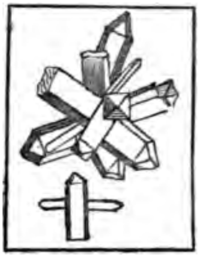

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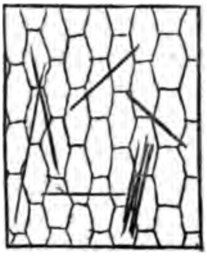


13

Among the tissue are found certain needle-shaped transparent bodies, lying either singly or in bundles, and called *raphides.* They were first discovered by Rafn, who found them in the milky juice of Euphorbiæ; afterwards they were met with by Jurine, in the leaves of Leucojum vernum, and elsewhere; and they are now well known to all vegetable anatomists. If a common Hyacinth is wounded, a considerable discharge of fluid takes place, and in this myriads of slender raphides (*fig.* 13.) are found floating; or if the cuticle of the leaf of Mirabilis Jalapa is lifted up, little whitish spots are observable, which are composed of them; all these are acicular in form, whence their name. In Cactus peruvianus (*fig.* 11.) they are found in the inside of the bladders of cellular tissue, and, instead of being needle-shaped, have the form of extremely minute conglomerated crystals, which, according to Turpin, are rectangular prisms with tetraedral summits, some with a square, others with an oblong base. Crystals of a similar figure have been remarked by the same observer in Rheum palmatum (*fig.* 12.); and their presence, according to him, is sufficient to distinguish samples really from China and Turkey, from those produced in Europe. The former abound in these crystals, the latter have hardly any. They are insoluble in alcohol, water, and caustic potash, but are dissolved by nitric acid.

Raphides are found solitary in the cells of Papyrus antiquorum, Epidendrum elongatum, &c., scattered in considerable numbers in the cells of Musa paradisiaca and collected firmly into bundles which are a little shorter than the cells in which they lie. They are in most instances formed in the cells of Merenchyma and Parenchyma without order; but Meyen has observed that in the bark of Viburnum Lantana they are principally stationed in the interior of thin-sided cells, clustered in cavities of thicker sided tissue.

Link compares the raphides in plants to calculi in animals.

Raspail asserts that raphides are never found either in Cactus or elsewhere in the inside of the bladders of cellular tissue, but are exclusively placed in the intercellular passages. The slender kind (*fig.* 13.) he states to be crystals of phosphate of lime, from $\frac{1}{10}$ to $\frac{1}{300}$ of a millimetre in length, and to be in reality six-sided prisms, terminated at each end by a pyramid with the same base. The crystals found in the Cactus and Rhubarb (*figs.* 11. and 12.), he says are composed of oxalate of lime; and he represents them to be right-angled prisms, terminating in a four-sided pyramid. (*Nouv. Syst. de Ch. Org.* p. 522.) According to Marquart the raphides of Aloe arborescens consist of phosphoric acid combined with lime and magnesia. Mohl says that raphides are never six-sided prisms, as Raspail asserts; but that they are right-angled four-sided prisms, which gradually vanish into points; and he declares that Meyen is right in asserting that the raphides are constantly formed inside the bladders, and never in the interstitial passages of cellular tissue (*Anat. Palm.* p. 28.); about which there is no sort of doubt. In Liparis pendula, in which the tissue is very thin, the raphides may be seen *in situ* without disturbing the surrounding parts, and they then form dense bundles of acicular crystals lying in the centre of cells.

The same circumstance is particularly visible in the oval cells found in the leaves of Caladium esculentum, Dieffenbachia Seguina, and some other Araceæ. Here the acicular raphides are not only collected in bundles inside the cells, but are expelled from them by an opening at each end of the cell, on which account Turpin calls such cells *Biforines.* Morren found the power of emitting their raphides preserved in these bodies after having undergone 6° of cold of Reaumur (18° Fahr.), and he therefore concludes that the phenomenon is, as Turpin supposes, a mere physical action produced by endosmose, and not a vital action.

(*For further remarks on raphides see the Appendix to this Work.*)

SECT. VII. *Of amylaceous and other granular matter contained in Tissue.*

INSIDE the tissue of plants, are found various kinds of particles, some of which give colour or its peculiar turbid appearance to the fluid, others their nutritive quality to particular species.

Of these some are turned blue by iodine, and are therefore regarded by chemists as composed of amylaceous matter or starch; others are rendered olive brown by that agent, and many are dissolved by alcohol, whence they are considered of the nature of resins: all are decomposed by cold, and appear to be connected with the function of nutrition.

The following kinds may be distinguished: —

1. *Amylaceous granules.*—These are so extremely common that no plant can be said to be destitute of them, and many have the cells of their roots and some parts of their stem filled quite full of them. In the rhizoma of Equisetum the tubes are so crowded with them, that when the tubes are wounded, the granules are discharged with some force, apparently by the contraction of the membrane, so that they appear as if in voluntary motion so long as the emptying the tissue continues to take place. These particles are perfectly white, semitransparent, generally irregularly oblong, sometimes compound, and marked with oblique concentric circles; they are extremely variable in size, some being as fine as the smallest molecular matter in pollen, that is, not more than $\frac{1}{25000}$

of an inch in diameter, others being as much as $\frac{1}{1000}$ or $\frac{1}{750}$. They often form the centre of the grains of chlorophyll, as Mohl has shown. In the milky juice of Euphorbia, they assume the singular appearance represented at Plate II. fig. 19. *b.*, looking like short cylinders enlarged at each end into a round head: double-headed granules of this kind are not as yet found elsewhere; Morren states that they vary in form in different species of Euphorbia.

Their nature has been carefully investigated by Fritzsche (*Ueber das Amylum*, Berlin, 1834, and *Poggendorf's Annalen*, 1834, No. 9, 10.), who has proved them to be formed by the successive deposit of new layers, one over the other, and not to be cells containing soluble matter, as Raspail asserts.

Those which have the smallest size have a distinct motion of rotation when suspended in water; and this motion looks as if spontaneous; for of several floating near each other, in the same medium, a part will be in active motion, while others remain inactive.

Turpin calls these granules *Globuline*, and considers them the most elementary conditions of vegetable tissue, its primitive form; an opinion which is adopted, with some modifications, by Raspail, who looks upon each granule as one of the elementary molecules of tissue in a state of development. This writer assigns them a point of attachment or hilum, by which they originally adhered to the parent cell: he considers that cellular tissue is produced by the development and mutual pressure of each granule, and that all the varied forms of plants may be explained by reference to this principle. (*Nouv. Syst. de Chimie Organique*, p. 83.) Morren states that these grains of fecula are the first stage of a crowd of organs, and that he can demonstrate the free spiral thread of Collomia and Salvia to be at first an amylaceous granule. This, however, does not correspond with the statements of Schleiden. Such amylaceous granules appear to have, under particular circumstances, the power of spontaneous growth, by which they multiply and increase themselves externally. This is particularly visible in the fecula of Barley; which, if observed in its original state, is found to be composed of angular, irregular bodies, some of which are of extreme minuteness, and seem to have a power of spontaneous motion in water. Shortly after germination the amylaceous bodies, according to Turpin, appear to lose their substance, to become more transparent and flaccid, a circumstance which he thinks is owing to the chemical change of their starch into sugar: the granules however at this time retain their property of becoming blue under the action of iodine. When this alteration has been produced, the maltster stops the new chemical action by heat and dryness, and fixes the sugar, as we see in malt. When the amylaceous granules are placed in water of a certain temperature, rendered sweet by the dissolution of their own sugar, and exposed to the influence of the oxygen of the atmosphere, they evidently produce little sprouts like themselves from their sides. Turpin states that, if examined after fermentation has been going on for some hours, they will be found to have each formed several new granules exactly like the mother-granules; and he not only considers this to be the cause of the curious phenomena observable in fermentation, but regards the granules as seeds and the result of their growth as a plant, which he calls *Torula cerevisiæ*. He adds, that in the inside of each of the new granules formed during fermentation, he finds a number of still smaller granules. I have not repeated the observations of this ingenious writer further than to ascertain that the granules in fermentation do sprout; and that they have at that time lost all their starch, for iodine produces no sensible effect upon their colour; a circumstance to which he has not adverted.

According to Schleiden amylaceous granules are gradually changed into gum and mucus in the process of lignification. (*Beiträge zur Phytogenesis*, p. 17.) This author considers starch to be analogous in plants to the fat in animals. It is nutritious matter in excess, laid by for future use, and is usually found in those places where new organization is about to commence, or where a luxuriance of vegetation has produced an excess of nutriment. Starch is sometimes represented by another half-granular matter, found in pollen, in the albumen of some plants, and abundantly in the Parenchyma of leaves, as the centre of the Chlorophyll. It is especially distinguished by presenting itself in irregular granular bodies without any internal structure, and becomes brownish yellow or brown when tested with tincture of iodine. This may be called mucus, and appears to be what the Cytoblast and its spherule are composed of. When starch is about to assume a new organization, it converts itself, in some manner unknown to chemists, into sugar or gum.

Sugar makes its appearance as a transparent fluid, which seems as clear as water, is not rendered turbid by alcohol, and is coloured by tincture of iodine, according to the greater or less degree of dilution of that agent.

Gum appears as a yellowish, more consistent, less transparent fluid, which, with tincture of iodine, coagulates into a pale yellow ungranulated colour. When vegetation has advanced to that point that gum is the latest immediate product, there appears in it a great many minute molecules, which are generally so small as to resemble dark points; at that time the fluid becomes a darker yellow upon the application of iodine. But the molecules, if they are large enough to show their colour, become dark-brown yellow. It is this mass, so transparent that it can hardly be seen till it is coloured, in which, in all cases, organization commences, and from which the youngest structure is constituted. It may be called Vegetable Jelly, and is probably nearly the same as Pecten, the base of Gum Tragacanth, and many other kinds of vegetable mucus. It is this jelly, which, by a further chemical attraction, becomes the membrane of cells, and is afterwards the material by which it is thickened.

2. *Chlorophyll* or *Chromule.* — To this is referred all the kinds of coloured granules which occupy the interior of vegetable tissue. They have a spheroidal, irregular figure, are often rather angular, consist of a semi-fluid gelatinous substance not contained in a sac, and which seems to be a coagulum of the fluid contents of the cells. The colour of plants, especially the green colour, is produced by the presence of chlorophyll, which may be considered a vital secretion. It will be mentioned more particularly in Book II., in the chapter upon colour.

3. *Latex granules.* — The interior of the laticiferous vessels is occupied by a fluid rendered turbid by the presence of infinite quantities of extremely minute particles which do not become blue upon the application of iodine, but which have a rapid motion upon their own axis. Of these little more is known than that they exist.

CHAPTER II.

OF THE COMPOUND ORGANS IN FLOWERING PLANTS.

HAVING now explained the more important circumstances connected with modifications in the elementary organs of vegetation, the next subject of enquiry will be the manner in which they are combined into those masses which constitute the external or compound organs, or in other words the parts which present themselves to us under the form of roots, stems, leaves, flowers, and fruit, and which constitute the apparatus performing all the actions of vegetable life. In doing this, I shall limit myself in the first place to Flowering Plants (*Introduction to the Natural System,* p. 1.); reserving for the subject of a separate chapter the explanation of some of the compound organs of Flowerless plants (*ibid.* p. 395.), which differ so much in structure from all others, as to require in most cases a special and distinct notice.

SECT. I. *Of the Cuticle and its Appendages.*

1. Of the Epidermis.

VEGETABLES, like animals, are covered externally by a thin membrane or epidermis, which usually adheres firmly to the cellular substance beneath it. To the naked eye it appears like a transparent homogeneous skin, but under the microscope it is found to be traversed in various directions by lines, which, by constantly anastomosing, give it a reticulated character. In some of the lower tribes of plants, consisting entirely of cellular tissue, it is not distinguishable, but in all others it is to be found upon every part exposed to the air, except the stigma and the spongelets of the roots. It is, however, as constantly absent from the surface of parts which live under water. Its usual character is that of a delicate membrane, but in some plants it is so hard as almost to resist the blade of a knife, as in the pseudo-bulbs of certain Orchidaceous plants. The most usual form of its reticulations is the hexagonal (Plate III. fig. 11.): sometimes they are exceedingly uncertain in figure; often prismatical; and not unfrequently bounded by sinuous lines, so irregular in their direction as to give the meshes no determinate figure (*fig.* 5.).

Botanists were formerly not agreed upon the exact nature of the epidermis; while some inclined to the opinion that it is an external layer of cellular tissue in a compressed state, others, among whom were included both Kieser and Amici, considered it a membrane of a peculiar nature, transversed by veins, or vasa lymphatica.

By the latter it was contended, that the sinuous direction of the lines in many kinds of epidermis is incompatible with the idea of any thing formed by the adhesion of cellular tissue; that when it is once removed, the subjacent tissue dies, and does not become epidermis in its turn, and that it may often be torn up readily without laceration.

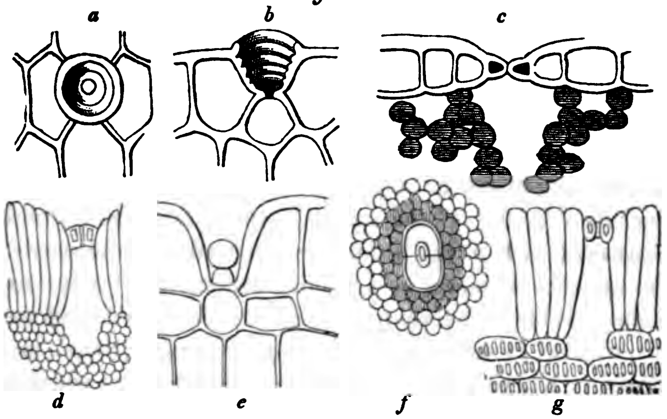
On the other hand, it was replied, that the reticulations of the epidermis are mostly of some figure analogous to that of cellular tissue, and that the sinuous meshes themselves are not so different as to be incompatible with the idea of a membrane formed of adhering bladders. We are accustomed to see so much variety in the mere form of all parts of plants, that an anomalous configuration in cellular tissue should not surprise us. The lines, or supposed lymphatic vessels, are nothing more than the united sides of the bladders, and are altogether the same as are presented to the eye by any section of a mass of cellular substance. It is certain that the epidermis cannot be removed without lacerating the subjacent tissue, with however much facility it may be sometimes separable: on the under surface of the leaf of the Box, for instance, there has plainly been some tearing of the tissue, before the epidermis acquired the loose state in which it is finally found.

There is now no anatomist to be found who doubts the fact of epidermis being cellular tissue. In many plants the cellular state is distinctly visible upon a section (Plate I. fig. 2. *a*); it even consists occasionally of several layers of vesicles, as in the Oleander and many Orchidaceæ, and it varies in the density, form, and arrangement of its component cells in different plants, according to the peculiar conditions to which they are exposed.

External to the epidermis is a thin homogeneous membrane, formed of organic mucus (see page 1.) and overlying every part except the stomates and the stigmatic tissue. It was first observed by Adolphe Brongniart in the Cabbage-leaf, afterwards by Henslow in Digitalis, and by myself in Dionæa; it has subsequently been the subject of more extended observations, and appears to be a universal coating, which is even drawn over the hairs, as if to protect the tender cell forming their interior, and the plexus of capillary Cinenchyma, which is stationed on the outside of the walls of that cell. I have found this cuticular membrane on the delicate petals of Hydrotænia Meleagris, from which it may be easily removed after maceration for a few days in spirit of wine; and Ad. Brongniart succeeded in separating it from the leaves of Potamogoton lucens, after very long maceration in water. It is stated to be sometimes covered with a minute granular appearance, the nature of which is unknown, and which is not found at the lines indicating the place where the cuticle was pressed upon the united sides of cells. There are some good observations upon this subject by M. Adolphe Brongniart (*Ann. des Sc.* 2 *ser.* 1. 65.), who finds the cuticle by no means uncommon; and imagines that it overlies the stigma in Nymphæa and Mirabilis. It certainly does not cover the stomates, nor the glands found on the surface of the inside of the pitchers of Nepenthes.

2. Of Stomates.

Fig. 14.



In most plants the cuticle has certain openings of a very peculiar character, which appear connected with respiration, and which are called *Stomates*, *Stomata*, or *Stomatia*. (Plate III. *passim.*)

Stomates are passages through the cuticle, having the appearance of an oval space, in the centre of which is a slit that opens or closes according to circumstances, and lies above a cavity in the subjacent tissue.

There is, perhaps, nothing in the structure of plants upon which more different opinions have been formed than these stomates. Malpighi and Grew, the latter of whom seems first to have figured them (t. 48., fig. 4.), call them openings or apertures, but had no exact idea of their structure. Mirbel also, for a long time, considered them pores, and figured them as such; admitting, however, that he suspected the openings to be an optical deception. De Candolle entertains no doubt of their being passages through the epidermis. He says their edge has the appearance of a kind of oval sphincter, capable of opening and shutting. The membrane that surrounds this sphincter is always continuous with that which constitutes the network of the epidermis: under the latter, and in the interval between the pore and the edge of the sphincter, are often found molecules of adhesive green matter (*Organogr.* i. 80.); and recently Adolphe Brongniart, in his beautiful figures of the anatomy of leaves, would seem to have settled the question beyond all dispute. (*Annales des Sciences*, vol. xxi.) Nevertheless there are anatomists of high reputation who entertain a directly opposite opinion; denying the existence of passages, and considering the stomates rather in the light of glands. Nees von Esenbeck and Link have denied the existence of any perforation in the stomates, and considered that the supposed opening is a space more pellucid than the surrounding tissue, and that what seems a closed up slit is the thickened border of the space. Link further added in his *Elementa* (ed. 1. p. 225.), that the obscuration of the centre of the stomates is caused by a peculiar secretion of matter, as is plainly visible in Baryosma serratum. To the views of these writers is to be added the testimony of Brown (*Suppl. prim. Prodr.* p. 1.), who describes the stomates as glands which are really almost always imperforate, with a disk formed by a membrane of greater or less opaqueness, and even occasionally coloured; at the same time he speaks of the disk being, *perhaps*, sometimes perforated. Link, however, has now abandoned his first idea (*Elementa*, ed. 2., vol. ii., p. 6.), recognising them as openings; and most anatomists have come to the same conclusion.

In no plants are stomates larger than in some Monocotyledons; they are, therefore, the best subjects for examination for general purposes. In Crinum amabile they evidently consist of two kidney-shaped bodies filled with green matter, lying in an area of the cuticle smaller than those that surround it, and having their incurved sides next each other. In some, at the part where the kidney-shaped bodies come in contact, there is an elevated ridge, dark, as if filled with air, and having its principal diameter distinctly divided by a line. (Plate III. fig. 11.) In this state the stomate is at rest: but in others the kidney-shaped bodies are much more curved; their sides are more separated from each other; and there is no elevated ridge: at their former line of contact there is an opening so distinct and wide as to be equal to half the diameter of one of the kidney-shaped bodies.

This structure of the stomate in Crinum amabile may be taken as the type of all others; for, no doubt, they are all constructed upon a similar plan, though modified in different species. That is to say they are composed of a pair of cells placed side by side, communicating freely with a hollow chamber in the parenchyma of the leaf built up of cells, arranged in various ways. (*Fig.* 14. *c* represents the appearance of the stomate in Acrostichum alcicorne when cut through perpendicularly; *figs. d* and *g* show it in the seed-coat of Cannas, and *fig. f* is the appearance of the same stomate seen from above; all these are copied from Dr. Schleiden's figures.) It is not, however, always two cells which by lying side by side form the stomate; occasionally a greater number is present; as in Marchantia, where, according to Mirbel, they are minute funnels in the epidermis, composed of four or five vesicles arranged circularly in several tiers; at the bottom of this funnel is a large square aperture, communicating with a subjacent chamber, and caused either by the destruction of a central vesicle, or by the separation of the sides of four or five vesicles at the angles next the centre of the funnel.

Several varieties are represented at Plate III.; besides which, stomates have been noticed by Link to be occasionally quadrangular, as in Yucca gloriosa (Plate III. fig. 10.), and Agave americana, and by Brown to be very rarely angular, of which, however, no instance is cited by that botanist. The former case is one in which the quadrangular figure is caused by the cellules of the opening being straight, and bounded by four other cells which appear to be inside the areolations of the cuticle. I have never been so fortunate as to discover the membrane which this great observer describes as generally overlying the apertures; nor do I know of any other botanist having confirmed that observation. It cannot be the cuticle already described, because it has been found that that part never overlies the stomates (see page 50.).

Nerium oleander, and some other plants have, in lieu of stomates, cavities in the cuticle, curiously filled up or protected by hairs. (See *Annales des Sciences*, xxi. 438.)

In Nepenthes there are stomates of two kinds, the one oblong, semi-transparent, and almost colourless, with numerous pellucid globules in the cavity of the cells; the other roundish, much more opaque, and coloured red. The latter do not communicate immediately with internal cavities in the parenchyma, but are in contact with an internal deep brownish-red gland, the lower side of which sometimes appears to have six regular plane faces obliquely resting upon a central face, or, in other cases, to be composed of six cells surrounding a seventh, all being filled with dark red colouring matter. The nature and use of these glands, and of the stomates that accompany them, is unknown. This is I believe the only case hitherto noticed, where the same species has stomates of different forms; it is also remarkable, because in one of these cases the stomate does not open into a chamber of the parenchyma, but immediately reposes upon a gland.

Although the usual condition of stomates is such as is above described, yet there are cases in which it is materially modified, and their function is changed. An instance of this occurs in Dionæa muscipula, in which the peculiar glands, placed in great numbers on the upper side of the lamina of the leaf, each proceed from a pair of parallel green cells, apparently of the same nature as the two cells forming the sphincter of a stomate.

In the epidermis of certain plants are openings resembling stomates, which require to be distinguished from them. In Nuphar luteum they occur in the form of circular depressions (*figs. a* and *b*), the sides of which are marked by elevated rings. In Peperomia pereskiæfolia (*fig. e*) they are deep impressions in the epidermis, at the bottom of which is a two-celled hair. These have been taken for stomates by Meyen, in a plant called by him Pleurothallis ruscifolia (*Wiegman's Arch.* 1837. *t.* 10. *figg.* 4, 5, 6, 7, 8, 9.); but according to Schleiden, the observations of this anatomist are incorrect, and all such appearances are either spaces left by the fall of hairs, whose bases fitted into the cavity, or formed for the reception of hairs, or depressions of entirely a different nature from stomates.

Stomates are not found in Mosses, Fungi, Algæ, or Lichens (see *Introduction to the Natural System*); in no submersed plants, or submersed plants of amphibious plants. They are not formed in the cuticle of plants growing in darkness, nor upon roots, nor the ribs of leaves. It frequently happens that they are found upon one surface of a leaf, but not on another, and generally in most abundance on the under side. In succulent parts they are neither rare nor wholly wanting, as has been often asserted; but are, on the contrary, as numerous as on many other parts. They may be generally seen upon the calyx; often on the corolla; and rarely, but sometimes, upon the filaments, anthers, and styles. In fruit, they have only been noticed upon such as are membranous, and not upon the coat of the seed; not even upon those seeds which, as in Leontice thalictroides, grow exposed to air; with the exception of the genus Canna, in which Dr. Schleiden has found them, and to which he thinks them necessary in order to facilitate the passage of fluid through them to the interior of the seed. They exist upon the surface of cotyledons.

Brown thinks that the uniformity of the stomates, in figure, position, and size, with respect to the meshes of the epidermis, is often such as to indicate the limits, and sometimes the affinities, of genera, and of their natural sections. He has shown, with his usual skill, that this is the case in Proteaceæ, in which statement he is supported by Schleiden, who seems to think that the structure of the stomatic opening will be modified according to the physiological peculiarities of particular species, and that it will often indicate affinity. He mentions Cactaceæ, Coniferæ, Piperaceæ, Agave, with some allied Liliaceæ, Commelinaceæ, and Grasses, in illustration of this. (*Wiegm. Arch.* 1838. p. 59.) Brown also remarks, that on the microscopic character of the equal existence of stomates on both surfaces of the leaf depends that want of lustre which is so remarkable in the forests of New Holland. (*Journal of the Royal Geogr. Society*, i. 21.)

The same botanist is of opinion, that the two glands, or rather bladders, of which a stomate is composed, are each analogous to the single bladders often found occupying the inner face of the meshes of the epidermis. (Plate III. fig. 9.) (See the *Memoir on the impregnation of Orchideæ.*) This idea is confirmed by the structure of Yucca (Plate III. fig. 10.), in which the four oblong vesicles surrounding the stomate are evidently of the same nature as the free spheroidal vesicles (cytoblasts?) contained in the cells of the cuticle.

The following table of the proportion of stomates on the surface of various organs will serve to give some idea of their relative abundance. The first twenty-eight cases are taken from Thomson's Treatise on Vegetable Physiology, in the Library of Useful Knowledge. For the remainder I am answerable: —

	Names of the plants on the leaves of which the stomates have been counted.	Number of stomates on one inch square surface.		
		On upper side.	On under side.	On both.
1	Andromeda speciosa	None	32,000	
2	Arum dracontium	8000	16,320	24,320
3	Alisma Plantago	12,000	6000	18,000
4	Amaryllis Josephinæ	31,500	31,500	63,000
5	Cobæa scandens	None	20,000	
6	Dianthus Caryophyllus	38,500	38,500	77,000
7	Daphne Mezereum	None	4000	
8	Epidendrum	None	4800	
9	Hypericum grandiflorum	None	47,800	
10	Hydrangea quercifolia	None	160,000	
11	Gærtnera	1000	142,750	143,750
12	Ilex	None	63,600	
13	Iris germanica	11,572	11,572	23,144
14	Olea europæa	None	57,600	
15	Pæonia	None	13,790	
16	Pittosporum Tobira	None	160,000	
17	Philadelphus coronarius	None	20,000	
18	Pyrus	None	24,000	
19	Sempervivum tectorum	10,710	6000	
20	Syringa vulgaris	None	160,000	
21	Rheum palmatum	1000	40,000	41,000
22	Rudbeckia	8000	41,000	49,000
23	Rumex acetosa	11,088	20,000	31,088
24	Theophrasta	None	172,032	
25	Tussilago farfara	1200	12,500	13,700
26	Tradescantia	2000	2000	4000
27	Vitis vinifera	None	13,600	
28	Viscum album	200	200	400
29	Viburnum Tinus	None	90,000	
30	Prunus Laurocerasus	None	90,000	
31	Crinum amabile	20,000	20,000	40,000
32	Stapelia (stem)	———	———	15,000
33	Alströmeria	None	20,000	
34	Mesembryanthemum	30,000	40,000	70,000
35	Aloe	25,000	20,000	45,000
36	Yucca	40,000	40,000	80,000
37	Cactus speciosissimus (stem)	———	———	15,000

The origin of stomates has always been very obscure, nor do I know of any one who has explained their origin in any detail except Schleiden, who considers them to be the last cytoblasts which the cuticular tissue forms (see page 19. for his theory of cytoblasts). He considers that in the beginning all the forms of tissue are, in shape, contents, and structure, exactly the same, and that all the modifications of tissue take place later. He supposes that the exterior tissue of a given mass leaves off producing new cells in its interior sooner than that of the exterior, and that consequently epidermis is first completely organised; but in the epidermis some of the cells retain longer than others the property of forming internal cells, and it is when the last pair of cells separate and absorb their parent that the stoma is produced. The cells forming the stomatic sphincter are in their origin exactly the same as the cells of the parenchyma, and they remain so in their functions throughout their whole existence.

Some physiologists, Link for instance, adhere to the opinion that stomates are glands or secreting organs, and not mere passages in the cuticle for the transmission of gaseous matter. Upon this subject I quote the words of Schleiden: —

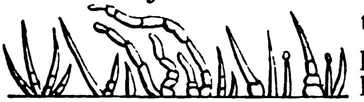
"These two cells (of the stoma) have been designated by the name, of glands, but I do not see any reason for this denomination being given to them in preference to any of the other exactly similar cells of parenchyma. From these they do not differ at all in the abstract, and in their position only apparently, inasmuch as it is a law that only two cells form an intercellular passage, not three or four; examples of which are not uncommon in the interior of plants. They contain, like the surrounding parenchyma, sometimes gum, sometimes globules of mucus (schleim), sometimes starch, these latter substances sometimes colourless, and sometimes coloured by chlorophyll, but always so that their contents are the same as those of the surrounding cells: but never, as I believe, does one find in them peculiar substances which might warrant the name of glands. In the single instance of Agave lurida I remember having seen a few drops of oil. The diversity of opinions as to whether the stomata be really open, leads to the supposition, of the correctness of which any one may easily convince themselves, that their remaining open is not at all caused by a constant exterior influence, but very probably depends upon the momentary vitality of the plant, or of the organ, or perhaps only of the surrounding cellular tissue. The substances which are deposited near and upon the stomata are considered by some, with more or less plausibility, as sufficient evidence that these substances cannot be abstracted from the epidermis itself, and then they jump to the conclusion that such substances are secreted by the stomata. I have, however, in vain looked for any facts which might make it even probable, that those secretions should arise rather from the evaporation of the so called glandular cells, than from those of the other parenchymatous cells, and more especially from such as border upon the cavities into which the stomata lead; and it appears to me that this assumed function is, in the present state of our knowledge, a mere *petitio principii.* Let us take the Coniferæ: here I find gum resin on the stomata; if I remove this by etherial oil, the stomata still remain wide open; then I find a cavity (including the two cells of the stomata), and surrounded by cells which contain gum (schleim), some starch and chlorophyll, but no traces of gum resin or turpentine; on the contrary, I find, much deeper down, large turpentine ducts, and conclude now that the fluid turpentine oil escapes from these passages in the form of vapour, and following the intercellular passages, arrives in the cavities, and from here evaporates by means of the stomata into the atmosphere, by which, as follows from its nature, it leaves behind a certain quantity of resin," &c.

The surface of the epidermis is either perfectly smooth, or furnished with numerous processes, consisting of cellular tissue in different states of combination, which may be arranged under the heads of *hair*, *scurf*, *glands*, and *prickles.* All these originate either directly from the epidermis, or from the cellular substance beneath it; never having any communication with the vascular or ligneous system.

In Nepenthes the cuticle in the inside of the pitchers is pierced by a great number of holes, each of which is closed up by a firm thick disk of small cellular tissue, deep brown in colour, and connected with the cavernous parenchyma of the pitcher. Of these more will be said under the head of GLANDS.

3. Of Hairs.

Fig. 15.



These (*fig.* 15.) are minute, transparent, filiform, acute processes, composed of cellular tissue more or less elongated, and arranged in a single row. They are found occasionally upon every part of a plant, even in the cavities of the petiole and stem, as in Nymphæa and other aquatic plants. In the Cotton Plant (Gossypium herbaceum, &c.) they form the substance which envelopes the seeds, and is wrought into linen; in the Cowhage (Mucuna urens and pruriens), it is they which produce the itching. In Ferns they are long, entangled, strangulated filaments. They vary extremely in length, density, rigidity, and other particulars; on which account they have received the following names:—

Down or *Pubescence* (*pubes*, adj. *pubescens*), when they form a short soft stratum, which only partially covers the cuticle, as in Geranium molle.

Hairiness (*hirsuties*, adj. *hirsutus*), when they are rather longer and more rigid, as in Galeopsis Tetrahit.

Pilosity (adj. *pilosus*), when they are long, soft, and erect, as in Daucus Carota.

Villosity (adj. *villosus*), when they are very long, very soft, erect, and straight, as in Epilobium hirsutum. *Crini* (adj. *crinitus*) are this variety in excess.

Velvet (*velumen*, adj. *velutinus*), when they are short, very dense and soft, but rather rigid, and forming a surface like velvet, as in many Lasiandras.

Tomentum (adj. *tomentosus*), when they are entangled, and close pressed to the stem, as in Geranium rotundifolium.

Ciliæ (adj. *ciliatus*), when long, and forming a fringe to the margin, like an eyelash, as in Sempervivum tectorum.

Bristles (*setæ*, adj. *setosus*), when short and stiff, as on the stems of Echium.

Stings (*stimuli*, adj. *stimulans*; *pili subulati* of De Candolle), when stiff and pungent, giving out an acrid juice if touched, as in the Nettle.

Glandular hairs (*pili capitati*), when they are tipped with a glandular exudation, as in Primula sinensis. These must not be confounded with stalked glands.

Hooks (*hami*, *unci*, *rostella*), when curved back at the point, as in the nuts of Myosotis Lappula.

Barbs (*glochis*, adj. *glochidatus*), if forked at the apex, both divisions of the fork being hooked, as in the nuts of the same plant.

Hairs also give the following names to the surface of any thing: —

Silky (*sericeus*), when they are long, very fine, and pressed closely to the surface, so as to present a sublucid silky appearance: *ex.* Protea argentea.

Arachnoid, when very long, and loosely entangled, so as to resemble cobweb: *ex.* Calceolaria arachnoidea.

Manicate, when interwoven into a mass that can be easily separated from the surface: *ex.* Cacalia canescens, Bupleurum giganteum.

Bearded (*barbatus*), when the hairs are long, and placed in tufts: *ex.* the lip of Chelone barbata.

Rough (*asper*), when the surface is clothed with hairs, the lower joint of which resembles a little bulb, and the upper a short rigid bristle: *ex.* Borago officinalis.

Stellate, or *starry*, when the hairs grow in tufts from the surface, and diverge a little from their centre, as in the Mallow tribe.

Hairs are either formed of a single cell of cellular tissue (Plate I. fig. 8. *b*, and Plate II. fig. 18.) or of several placed end to end in a single series, (Plate I. fig. A, B,) whence, if viewed externally, they have the appearance of being divided internally by transverse partitions. They are sometimes branched into two or three forks at the extremity, as in Alyssum, some species of Apargia, &c. Occasionally they emit little branches along their whole length: when such branches are very short, the hairs are said to be *toothed* or *toothletted*, as in the fruit of Torilis Anthriscus; when they are something longer, the hairs are called *branched*, as in the petioles of the gooseberry; if longer and finer still, the hair is *pinnate*, as in Hieracium Pilosella; if the branches are themselves pinnate, as in Hieracium undulatum, the hairs are then said to be *plumose*. It sometimes happens that little branchlets are produced on one side only of a hair, as on the leaves of Siegesbeckia orientalis, in which case the hair is called *one-sided* (*secundatus*); very rarely they appear upon the articulations of the hair, which in that case is called *ganglioneous*. (Plate I. fig. 9. Verbascum Lychnitis): the *poils en goupillon* of De Candolle are referable to this form. Besides these, there are many other modifications: hairs are conical, cylindrical, or moniliform, thickened slightly at the articulations (*torulose*), as in Lamium album, or much enlarged at the same point (*nodulose*), as in the calyx of Achyranthes lappacea. In Polystachya luteola the hairs of the labellum are *moniliform*, or necklace-shaped, with the articulations all spheroidal, equal sized, and disarticulating at the slightest touch when the flower is expanded, so that the part on which they grow seems as if it were covered with fine powder.

Hairs are sometimes said to be *fixed by their middle* (Plate I. fig. 10. *c*); a remarkable structure, common to many different genera: as Capsella, Malpighia, Indigofera, &c. This expression, however, like many others commonly used in botany, conveys a false idea of the real structure of such hairs. They are in reality formed by an elevation of one bladder of the epidermis above the level of the rest, and by developement of a simple hair from its two opposite sides. Such would be more correctly named *divaricating* hairs. When the central bladder has an unusual size, as in Malpighia, these hairs are called *poils en navette* (*pili Malpighiacei*) by De Candolle, and when the central bladder is not very apparent, *poils en fausse navette* (*pili pseudo-Malpighiacei, biacuminati*), as in Indigofera, Astragalus asper, &c. In many plants the hairs grow in clusters, as in Malvaceæ, and are occasionally united at their base: such are called *stellate*, and are frequently peculiar to certain natural orders. (Plate I. fig. 10. *a.*)

All these varieties belong to one or other of two principal kinds of hairs; viz. the Lymphatic and the Secreting. Of these, *lymphatic* hairs consist of tissue either tapering gradually from the base to the apex, or at least not much enlarged at either end; and *secreting*, of cellules visibly distended either at the apex or base into receptacles of fluid. Malpighiaceous and glandular hairs, stings, and those which cause asperity on the surface of any thing, belong to the latter; almost all the other varieties to the former.

When hairs arise from one surface only of any of the appendages of the axis, it is almost always from the under surface; but the seed-leaves of the nettle, and the common leaves of Passerina hirsuta, are mentioned by De Candolle as exceptions to this rule: certain states of Rosa canina might also be mentioned as exhibiting a similar instance. When a portion only of the surface of any thing is covered by hairs, that portion is uniformly the ribs or veins. According to De Candolle, hairs are not found either upon true roots, except at the moment of germination, nor upon any portion of the stem that is formed under ground, nor upon any parts that grow under water.

In a very large number of hairs, perhaps in all, there may be seen, at some period of their existence in any cell, a cytoblast, and a circulating system, formed of numerous fine streams, which all appear to proceed from and return to the cytoblast itself. (See Plate II. fig. 13. 14. 18.) In the moniliform disarticulating hairs of Polystachya, already described, each joint of the hair has this structure in a very remarkable manner.

If hairs are examined with low magnifying powers, their sides appear to be simple, and they are accordingly regarded as mere expansions or attenuations of the vesicles of the epidermis: but if they are studied with more attention and more powerful microscope, it becomes evident that their sides are double; for currents may often be seen streaming along their sides, and evidently interposed between the external smooth surface and an uneven interior membrane. This is easily observed in the jointed hairs of Tradescantia virginica, where the nature of the current is distinctly shown by minute molecules, that are carried along by the stream. If the hair of Tradescantia is suffered to die on the field of the microscope, and dry up, it then becomes evident that it is composed of two sacs, the one firm and external, the other extremely thin, and after death contracting so much as to leave a considerable space between its sides and the external sac. (See Plate II. fig. 14. *b.*) It appears to me that this is the general structure of all hairs in which a circulation of sap, and the cytoblast are both visible; and it is probable that the external sac is the cuticular membrane, hard, firm, and scarcely capable of shrivelling; while the internal sac is a cell of the parenchyma, thin-sided, and not acquiring any firmness with age, but shrivelling up as soon as the fluid which distends it when alive is withdrawn.

4. Of Scurf.

SCURF consists of thin flat membranous disks, with a ragged margin, formed of cellular tissue, springing from the epidermis. It may be considered as a modification of hairs; for it differs from those bodies only in being more compound. It is of two kinds, *Scurf*, properly so called, and *Ramenta.*

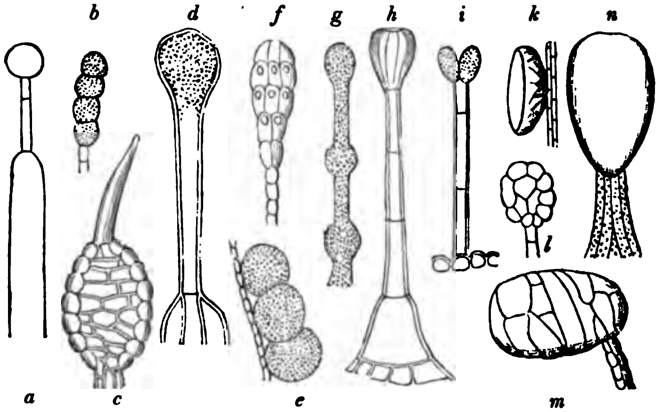
Scurf, properly so called, are the small, roundish, flattened, particles which give a leprous appearance to the surface of certain plants, as the Elæagnus and the Pine Apple. (Plate I. fig. 10. *b.*) They consist of a thin transparent membrane, attached by its middle, and, owing to the imperfect union, towards its circumference, of the cellular tissue of which it is composed, having a lacerated irregular margin. A scale of this nature is, in Latin, called *lepis,* and a surface covered by such scales *lepidotus* — not *squamosus,* which is only applied to a surface covered with the rudiments of leaves. Scurfs are the *poils en écusson* (*pili scutati*) of De Candolle.

Ramenta (*Vaginellæ*) are thin, brown, foliaceous scales, appearing sometimes in great abundance upon young shoots.

They are particularly numerous, and highly developed, upon the petioles and the backs of the leaves of Ferns. They consist of cellular tissue alone, without any vascular cords, and are known from leaves not only by their anatomical structure, but also by their irregular position, and by the absence of buds from their axils. The student must particularly remark this, or he will confound with them leaves having a ramentaceous appearance, such as are produced upon the young shoots of Pinus. Link remarks, that they are very similar in structure to the leaves of mosses. The term *striga* has occasionally been applied to them (*Dec. Théor. Elém.* ed. 2. 376. *Link, Elém.* 240.); but that word was employed by Linnæus to designate any stiff bristle-like process, as the *spines* of the Cactus, the divaricating *hairs* of Malpighia, and the stiff stellated *hairs* of Hibiscus. So vague an application of the term is very properly avoided at the present day, and the substantive is rejected from modern glossology; the adjective term *strigose* is, however, occasionally still employed to express a surface covered with stiff hairs.

5. Of Glands.

Fig. 16.



Glands are small collections of firm cellular tissue, which is often much harder and more coloured than that which surrounds it. They are of several kinds.

Stalked glands (*fig.* 16. *a*, *b*, *c*, *d*, *f*, *h*, *i*, *l*, *m*, *n*,) are elevated on a stalk which is either simple or branched: they secrete some peculiar matter at their extremities, and are often confounded with the glandular hairs above described, from which they have been well distinguished by Link. According to that botanist, they are either simple (*fig.* 16. *a*, *b*, *d*, *g*, *h*, *i*,) or compound (*c*, *f*, *k*, *l*, *m*); the former consisting of a single cell, and placed upon a hair acting as a simple conduit, occasionally interrupted by divisions; the latter consisting of several cells, and seated upon a stalk containing one or more conduits, formed by rows of cellular tissue. They are common upon the rose and the bramble, in which they become very rigid, and assume the nature of aculei. For the sake of distinguishing them from the latter, they have been called *setæ* by Woods and myself, but improperly; they are also the *aiguillons* of the French. In Hypericum they abound on the calyx and corolla of some species, but do not give out any exudation; they contain, however, a deep red juice within their cells. In some Jatrophas they are much branched; in many Rutaceæ they form a curious humid appendage at the apex of the stamens. Lately the glandular apparatus of plants has received the attention of Meyen, who has published on the subject an elaborate paper, from which the foregoing figures are taken. He admits the distinction of simple and compound glands, and regards them both as unquestionable organs of secretion. To some of the former he assigns occasionally more cells than one in the gland that terminates them; but the hair to which they belong is always simple. Of the compound glands some are hollow, others solid. They both vary exceedingly in form. Of the above figures the following brief descriptions will serve to illustrate the subject sufficiently for an introductory work: —

Simple Glands:—*a*, a simple stalked gland, from the outside of the flower of Sinningia barbata; it consists of a cylindrical cell springing from the epidermis, then of two smaller cells, and finally of a fourth, which is the gland; *b* is a gland composed of six cells, of which the two lower are small, cylindrical, and colourless, forming a stalk, the four upper spherical, larger, and filled with secreted matter; *d*, simple pestle-shaped glands of Sisymbrium chilense; in the pestle there is a yellow volatile oil; at the base are three cells of the epidermis; *g*, from the inside of the under-lip of Antirrhinum majus: the cell containing the glandular matter is at first cylindrical; it then forms a head, from which another cylindrical joint is emitted, to which a second head is afterwards formed, and upon which another joint with its head is eventually developed; *h* is a stalked gland from the stem of the same plant; *i*, a double-headed gland from the flower stalk of Lysimachia vulgaris.

Compound Glands:—*c*, a compound sessile gland of Dictamnus albus, consisting of a skin which is colourless, and a centre which is filled with a thick green etherial oil; *f*, compound glands from the flower stalk of Sanguisorba carnea; *k*, a side view of the compound gland of the hop, which chemists call *Lupulin* (Meyen entirely denies the accuracy of Raspail's description of this body); *l*, a compound red gland from Ailanthus glandulosa; *m*, oblong stalked glands from Begonia platanifolia: they resemble drops of resin, or something of that sort.

Other modifications of glandular apparatus are what some botanists call *papulæ*, or *papillæ* (*fig.* 16. *e* and *n*.)

Glandulæ utriculares of Guettard; these are transparent elevated points of the epidermis, filled with fluid, and covering closely the whole surface upon which they appear. In other words, they are elevated, distended bladders of the epidermis. The presence of papillæ upon the leaves of the ice plant gives rise to the peculiar crystalline nature of its surface.

There are, moreover, in many plants *internal glands*, that is to say, collections of cells densely compacted, and filled with secreted matter which hardens them, or renders them transparent. They are in some cases nearly of the nature of cysts, already described. In Dictamnus alba they form spherical nuclei, lying just below the cuticle, and filled with an etherial oil, rich in resin and camphor (*fig.* 10.) In Nepenthes they occur in two different states; the one as angular nuclei below one of the forms of stomate found in that plant; the other as hard, deep brown disks, lining the cavity of the pitcher, sunk below the epidermis, through which there are openings corresponding with them, and no doubt forming the apparatus by which the water contained in the pitcher is secreted. They have been noticed and figured by Meyen, but were long before mentioned in this work (1835), and have been figured by me in the second volume of Lady's Botany (t. 47.). The opening through the cuticle immediately above them shows that they are internal organs; nevertheless, Meyen considers them external glands. Internal glands are very common in Labiatæ.

Sessile glands, *verrucæ*, or *warts*, are produced upon various parts, and are extremely variable in figure. In Cassias, they are seated upon the upper edge of the petiole, and are usually cylindrical or conical; in Cruciferous plants they are little roundish shining bodies, arising from just below the base of the ovary; in the leafless Acacias they are depressed, with a thickened rim, and placed on the upper edge of the phyllodium; they are little kidney-shaped bodies upon the petiole of the Peach and other drupaceous plants; and they assume many more appearances. They are common upon the petiole, as in Passiflora; they are also found upon the calyx, as in some species of Campanula, and at the serratures of the leaves, when they are considered by Röper (*De Floribus Balsaminearum*, p. 15.) to be abortive ovules; and they appear upon the pericarp and the skin of the seed; in the latter case they are called *spongiolæ seminales* by De Candolle. In figure they are round, oblong, or reniform, and occasionally cupulate, when they receive the name of *glandes à godet* (*glandulæ urceolares*) from some French writers. Warts are the *glandes cellulaires* of Mirbel; but they must not be confounded with the *glandes vasculaires* of the same writer, which are not mere excrescences of the epidermis, but modifications of well known organs. (See *Discus*, further on.) Of this nature are the hypogynous glands of Cruciferous plants aleady referred to.

Lenticular glands (*Lenticelles* of De Candolle; *Glandes lenticulaires* of Guettard;) are brown oval spots found upon the bark of many plants, especially willows: they have been thought to indicate the points from which roots will appear if the branch be placed in circumstances favourable to their production, and are considered by De Candolle to bear the same relation to the roots that buds bear to young branches. (*Premier mém. sur les Lentic.*, in the *Ann. des Sciences Naturelles.*) In Tree ferns it is hardly posssble to doubt that the tubercles so common on the surface of the trunk, are the points of roots either prepared for developement, or arrested in their growth by the dryness of the air that surrounds them; for we find (in Dicksonia arborescens, for instance) that the part of the stem which is next the ground is covered with roots, and the part above it, surrounded by drier air, is covered with tubercles. But it is not at all improbable that the lenticular glands of the stems of ordinary trees, and the tubercles of tree ferns are different bodies, although confounded under one name.

It is extremely doubtful whether true lenticular glands are any thing more than portions of the epiphlœum, disorganised by some unknown power. Mohl states that they are found in the epiphlœum, that is, between the epidermis and the mesophlœum, and consist of greenish or colourless (or in Berberis yellow, and Sambucus red) cells which lie in rows perpendicular to the axis of the branch, and united towards the interior with the mesophlœum. He considers them a partial formation of cork.* Unger compares the true lenticular glands to the Soredia of Lichens, and the reproductive granulations of Jungermanniaceæ; and he considers them in some way connected with the respiratory process: even as obliterated respiratory organs. Meyen regards them, not as obliterated respiratory organs, but as formations intended to maintain an air communication between the exterior rind and the new green bark of trees; for he says that the tissue of old bark is so compactly combined as to cut off all direct communication between the air and the cavernous parenchyma of the green bark.

6. Of Prickles.

Prickles (*aculei*) are rigid, opaque, conical processes, formed of masses of cellular tissue, and terminating in an acute point. They may be, not improperly, considered as very compound hardened hairs. They have no connection with the woody tissue, by which character they are obviously distinguished from *spines*, of which mention will be made under the head of branches; but are a developement of the epiphlœum of the bark. According to Dutrochet (*Mémoires*, i. 174.), it is exclusively by the base where the epiphlœum and prickle are in contact, that the developement takes place of cells to increase the prickle in size. In the Rose the prickle is formed in one year, and afterwards dies. In Xanthoxylon juglandifolium it is the produce of two or three years' growth, according to the last mentioned author. Prickles are found upon all parts of a plant, except the stipules and stamens. They are very rarely found upon the corolla, as in Solanum Hystrix; their most usual place is upon the stem, as in Rosa, Rubus, &c.

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* I take this from Taylor's Magazine, xii. 58, where there is an (imperfect?) translation of Meyen's report on this and other subjects. Mohl's original paper I have not seen, and the translation is in part unintelligible.

SECT. II. *Of the Stem, or Ascending Axis.*

WHEN a plant first begins to grow from the seed, it is a little body called an embryo, with two opposite extremities, of which the one lengthens in the direction of the earth's centre, and the other, taking a direction exactly the contrary, extends upwards into the air. This disposition to develope in two diametrically opposite directions is found in all seeds, properly so called, there being no known exception to it; and the tendency is moreover so powerful, that, as we shall hereafter see (Book II.), the most powerful external influence is rarely sufficient to overcome it. The result of this developement is the axis, or centre, round which the leaves and other appendages are arranged. That part which forces its way downwards constantly avoiding light, and withdrawing from the influence of the air, is the descending axis, or the root; and that which seeks the light, always striving to expose itself to the air, and expanding itself to the utmost extent of its nature to the solar rays, is the ascending axis, or the stem. The only exception to this is when the embryo first begins to grow. At that time the first part of the axis formed below the cotyledons belongs to the stem, and it is only after the first joint of the stem, however minute and short it may be, is completed, that a root is formed. This will be more particularly explained hereafter; see Section XIV. of this chapter. As the double elongation just mentioned exists in all plants, it follows that all plants must necessarily have, at an early period of their existence at least, both stem and root; and that, consequently, when plants are said to be rootless, or stemless, such expressions are not to be considered physiologically correct.

The STEM has received many names; such as *caudex ascendens*, *caudex intermedius*, *culmus*, *stipes*, *truncus*, and *truncus ascendens*. It consists of bundles of vascular and woody tissue, embedded in cellular substance in various ways, and the whole enclosed within an epidermis. The manner in which these parts are arranged with respect to each other will be explained hereafter. The more immediate subject of consideration must be those organs which are common to all stems.

1. Of its Parts.

Where the stem and root, or the ascending and descending axis diverge, there commences in many plants a difference of anatomical structure, and in all a very essential physiological dissimilarity; as will be hereafter seen. This portion of the axis is called the neck or collum, (*coarcture* of Grew, *nœud vital* of Lamarck, *limes communis*, or *fundus plantæ*, of Jungius,) and has been thought by some to be the seat of vegetable vitality; an erroneous idea, of which more will be said in the next book. At first it is a space that we have no difficulty in distinguishing, so long as the embryo, or young plant, has not undergone any considerable change; but in process of time it is externally obliterated; so that in trees of a few years' growth its existence becomes a matter of theory, instead of being actually evident to our senses.

Immediately consequent upon the growth of a plant is the formation of leaves. The point of the stem from whence these arise is called the *node* (*geniculum*, Jungius), and the space between two nodes is called an *internode* (*merithallus*, Du Petit Thouars). In internodes the arrangement of the vascular and woody tissue, of whatever nature it may be, of which they are composed, is nearly parallel, or, at least, experiences no horizontal interruption. At the nodes on the contrary, vessels are sent off horizontally into the leaf; the general developement of the axis is momentarily arrested while this horizontal communication is effecting, and all the tissue is more or less contracted. In many plants this contraction, although it always exists, is scarcely appreciable; but in others it takes place in so remarkable a degree as to give their stems a peculiar character; as, for instance, in the Bamboo, in which it causes diaphragms that continue to grow and harden, notwithstanding the powerfully rapid horizontal distention to which the stems of that plant are subject. In all cases, without exception, a leaf-bud or buds is formed at a node immediately above the base of the leaf; generally such a bud is either sufficiently apparent to be readily recognised by the naked eye, or, at least, it becomes apparent at some time or other; but in certain plants, as Heaths, the buds are often never discoverable; nevertheless, they always exist, in however rudimentary a state, as is proved by their occasional developement under favourable or uncommon circumstances. By some writers nodes, upon which buds are obviously formed, are called *compound*, or *artiphyllous*; and those in which no apparent buds are discoverable, are named *simple*, or *pleiophyllous*; they are also said to be *divided*, when they do not surround the stem, as in the apple and other alternate-leaved genera; or *entire*, when they do surround it, as in grasses and umbelliferous plants: they are further said to be *pervious*, when the pith passes through them without interruption; or *closed*, when the canal of the pith is interrupted, as if by a partition. Pervious and divided, and closed and entire nodes usually accompany each other. For other remarks upon this subject, see Link's *Elementa*, and the Appendix to this volume.

All the divisions of a stem are in general terms called *branches* (*rami*); but it is occasionally found convenient to designate particular kinds of branches by special names. Thus, the twigs, or youngest shoots, are called *ramuli*, or branchlets, and by the older botanists *flagella;* the assemblage of branches which forms the head of a forest tree is called the *coma: cyma* is sometimes used to express the same thing, but improperly. Shoots which have not completed their growth have received the name of *innovations*, a term usually applied in mosses. When such a shoot is covered with scales upon its first appearance, as the Asparagus, it is called *turio:* by the old botanists all such shoots were named *asparagi.* When a shoot is long and flexible, it receives the name of *vimen.* This word, however, is seldom used; its adjective being employed instead: thus, we say, *rami viminei*, or *caulis vimineus;* and not *vimen.* From this kind of branch, that called a *virgate* stem, *caulis virgatus*, differs only in being less flexible. A young slender branch of a tree or shrub is sometimes named *virgultum.* When the branches diverge nearly at right angles from the stem, they are said to be *brachiate.* Small stems, which proceed from buds formed at the neck of a plant without the previous production of a leaf, are called *cauliculi.*

Link calls a stem which proceeds straight from the earth to the summit, bearing its branches on its sides, as Pinus, a *caulis excurrens*, and a stem which at a certain distance above the earth breaks out into irregular ramifications, a *caulis deliquescens.*

From the constitution and ramifications of their branches, plants are divided into trees, shrubs, and herbs. If the branches are perennial, and supported upon a. trunk, a *tree* (*arbor*) is said to be formed; for a small tree, the term *arbusculus* is sometimes employed. When the branches are perennial, proceeding directly from the surface of the earth without any supporting trunk, we have a shrub (*frutex* or *arbustum*, Lat.), which occasionally, when very small, receives the diminutive name of *fruticulus.* If a shrub is low, and very much branched, it is often called *dumosus* (subst. *dumus*). The *suffrutex*, or *under-shrub*, differs from the shrub, in perishing annually, either wholly or in part; and from the herb, in having branches of a woody texture, which frequently exist more than one year: such is the Mignionette (Reseda odorata) in its native country, or in the state in which it is known in gardens as the Tree Mignionette. The under-shrub is exactly intermediate between the shrub and the herb. All plants producing shoots of annual duration from the surface of the earth are called herbs.

Some botanists distinguish two sorts of stems, the characters of which are derived from the mode of growth. When a stem is never terminated by a flower-bud, nor has its growth stopped by any other organic cause, as in Veronica arvensis, and all perennial and arborescent plants, it is said to be *indeterminate;* but when a stem has its growth uniformly stopped at a particular period of its existence by the production of a terminal bud, or by some such cause, it is called *determinate.* The capitate and verticillate species of Mint owe their differences to causes of this nature; the stem of the former being determinate, the latter indeterminate.

The point whence two branches diverge is called the *axil*, or, in old botanical language, the *ala.*

Leaf-buds (*Gemma*, Linn.), being the rudiments of young branches, are of great importance in regard to the general structure of a plant. They consist of scales imbricated over each other, the outermost being the hardest and thickest, and surrounding a minute cellular axis, or *growing point*, which is in direct communication with the woody and cellular tissue of the stem. In other words, they may be said to be growing points covered with rudimentary leaves for their protection,

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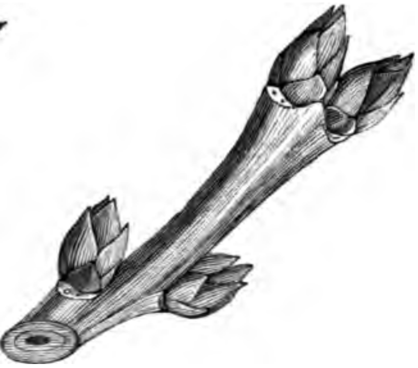

and to consist of a highly excitable mass of cellular substance, originating in the pith, and having a special power of extension in length. Under ordinary circumstances, the growing point clothes itself with leaves as it advances, and then it becomes a branch; but sometimes it simply hardens as it grows, and forms a sharp conical projection called a *spine*, as in the Gleditschia, the Sloe, &c.

The spine must not be confounded with the prickle or aculeus already described, from which it differs in having a considerable quantity of woody tissue in its structure, and in being as much in communication with the central parts of a stem as branches themselves; while prickles are merely superficial concretions of hardened cellular tissue. Spines occasionally, as in the Whitethorn, bear leaves; in domesticated plants they often entirely disappear, as in the Apple and Pear, the wild varieties of which are spiny, and the cultivated ones spineless.

We ought to consider the spadix of the Arum, and several forms of disk hereafter to be described, as modifications of the growing point of the bud, and consequently as analogous to spines.

Linnæus called the bud *Hybernaculum*, because it serves for the winter protection of the young and tender parts; and distinguished it into the *Gemma*, or leaf-bud of the stem, and the *Bulb*, or leaf-bud of the root.

The leaf-bud has been compared by Du Petit Thouars and some other botanists to the embryo, and has even been denominated a *fixed embryo*. This comparison must not, however, be understood to indicate any positive identity between these two parts in structure, but merely an analogous function, both being formed for the purpose of reproduction; but in origin and structure they are entirely different. The leaf-bud consists of both vascular and cellular tissue, the embryo of cellular tissue only: the leaf-bud is produced without fertilization, to the embryo this is essential: finally, the leaf-bud perpetuates the individual, the embryo continues the species.

The usual, or normal, situation of leaf-buds is in the axil of leaves; and all departure from this position is either irregular or accidental. Botanists give them the name of *regular* when they are placed in their normal station, and they call all others *latent* or *adventitious*. The latter have been found in almost every part of plants; the roots, the internodes, the petiole, the leaf itself, have all been remarked producing them. On the leaf they usually proceed from the margin, as in Malaxis paludosa, where they form minute granulations, first determined to be buds by Henslow, or as in Bryophyllum calycinum and Tellima grandiflora; but they have been seen by Turpin (fig. 19.) proceeding from the surface of the leaf of Ornithogalum. (Fig. 20. represents a vertical section of one of these buds.)

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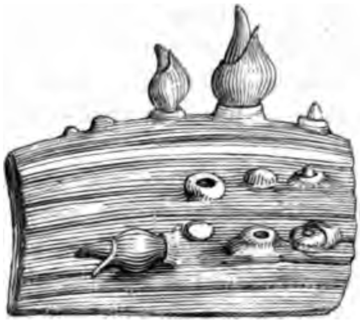

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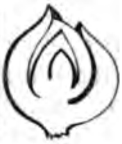

We are unacquainted with the cause of the formation of leaf-buds; all we know is, that they proceed exclusively from cellular tissue; and if produced on the stem, from the mouths of medullary rays. It would seem as if certain unknown forces were occasionally so exerted upon a vesicle of cellular tissue as to stimulate it into a preternatural degree of activity, the result of which is the production of vessels, and the formation of a nucleus having the power of lengthening. There is, indeed, an opinion, which I believe is that of Mr. Knight, that the sap itself can at any time generate buds without any previously formed rudiment; and that buds depend, not upon a specific alteration of the arrangement of the vascular system, called into action by particular circumstances, but upon a state of the sap favourable to their creation. In proof of this it has been said, that if a bud of the Prunus Pseudo-cerasus, or Chinese Cherry, be inserted upon a cherry stock, it will grow freely, and after a time will emit small roots from just above its union with the stock; at the time when these little roots are formed, let the shoot be cut back to within a short distance of the stock, and the little roots will then, in consequence of the great impulsion of sap into them, become branches emitting leaves.

The leaf-buds of the deciduous trees of cold climates are covered by scales, which are also called *tegmenta;* these afford protection against cold and external accidents, and vary much in texture, thickness, and other characters. Thus, in the *Beech*, the scales are thin, smooth, and dry; in many *Willows* they are covered with a thick down; in *Populus balsamifera* they exude a tenacious viscid juice. In herbaceous plants and trees of climates in which vegetation is not exposed to severe cold, the leaf-buds have no scales; which is also, but very rarely, the case in some northern shrubs, as Rhamnus Frangula.

The scales of the bud, however dissimilar they may be to leaves in their ordinary appearance, are nevertheless, in reality, leaves in an imperfectly formed state. They are the last leaves of the season, developed at a period when the current of vegetation is stopping, and when the vital powers have become almost torpid. That such is really their nature is apparent from the gradual transition from scales to perfect leaves that occurs in such plants as Viburnum prunifolium, Magnolia acuminata, Liriodendron Tulipifera, and Æsculus Pavia: in the latter the transition is, perhaps, most satisfactorily manifested. In this plant the scales on the outside are short, hard, dry, and brown; those next them are longer, greenish, and delicate; within these they become dilated, are slightly coloured pink, and occasionally bear a few imperfect leaflets at their apex; next to them are developed leaves of the ordinary character, except that their petiole is dilated and membranous like the inner scales of the bud; and, finally, perfectly formed leaves complete the series of transitions.

Among the varieties of root is sometimes classed what botanists call a *bulb;* a scaly body, formed at or beneath the surface of the ground, emitting roots from its base, and producing a stem from its centre. Linnæus considered it the leaf-bud of a root; but in this he was partly mistaken, roots being essentially characterised by the absence of buds. He was, however, perfectly correct in identifying it with a leaf-bud. A bulb has the power of propagating itself by developing in the axils of its scales new bulbs, or what gardeners call *cloves*, (*Nucleus* and *Adnascens* of the older botanists; *Adnatum* of Richard;) which grow at the expense of their parent bulb, and eventually destroy it. Every true bulb is, therefore, necessarily formed of imbricated scales, and a solid bulb has no existence. The *bulbi solidi*, as they have been called, of the Crocus, the Colchicum, and others are, as we shall hereafter see (see *Cormus*), a kind of subterranean stem: they are distinct from the bulb in being, not an imbricated scaly bulb, but a solid fleshy stem, itself emitting buds. It has been supposed that they were buds, the scales of which had become consolidated; but this hypothesis leads to this very inadmissible conclusion, — that as the cormus or solid bulb of a Crocus is essentially the same, except in size and situation, as the stem of a Palm, the stem of a Palm must be a solid bulb also, which is absurd. In truth, the bulb is analogous to the bud that is seated upon the cormus, and not to the cormus itself; a bulb being an enlarged subterranean bud without a stem, the cormus a subterranean stem with buds on its surface.

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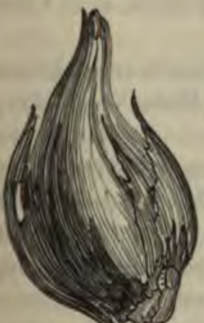

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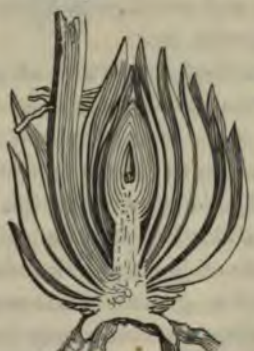

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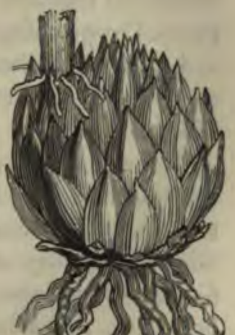


Of the bulb, properly so called, there are two kinds.

1. The *tunicated bulb* (*fig.* 21.), of which the outer scales

are thin and membranous, and cohere in the form of a distinct covering, as in the onion: and 2. the *naked bulb* (*Bulbus squamosus*) (fig. 22, 23.), in which the outer scales are not membranous and united, but distinct and fleshy like the inner scales, as in *Lilium*. The outer covering of a bulb of the first kind is called the *tunic*.

Besides the bulbs properly so called, there are certain leaf-buds, developed upon stems in the air, and separating spontaneously from the part that bears them, which are altogether of the nature of bulbs. Such are found in Lilium tigrinum, some Alliums, &c. They have been called *bulbilli*, *propagines*, *bacilli*, &c. Care must be taken not to follow some botanists, in confounding with them the seeds of certain Amaryllidaceæ, which have a fleshy coat; but which, with a vague external resemblance to bulbs, have in every respect the structure of genuine seeds.

The *tegmenta*, or scales of the bud, have received the following names, according to the part of the leaf of which they appear to be a transformation; such terms, are, however, but seldom employed: —

1. *foliacea*, when they are abortive leaves, as in Daphne Mezereum.

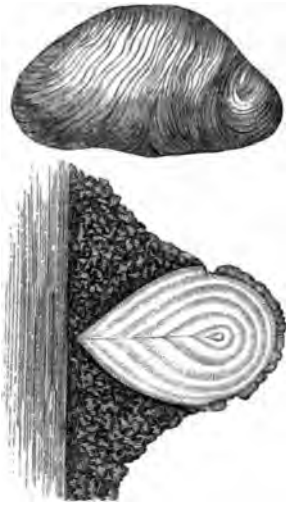
2. *petiolacea*, when they are formed by the persistent base of the petiole, as in Juglans regia.

3. *stipulacea*, when they arise from the union of stipules, which roll together and envelope the young shoot, as in Carpinus, Ostrya, Magnolia, &c.

4. *fulcracea*, when they are formed of petioles and stipules combined, as in Prunus domestica, &c. — (*Rich. Nouv. Elem.* 134. ed. 3.)

The manner in which the young leaves are arranged within the leaf-bud is called *foliation*, or *vernation*. The names applied to the various modifications of this will be explained in Glossology; they are of great practical importance both for distinguishing species, genera, and even natural orders; but have, nevertheless, received very little general attention. The vernation of Prunus Cerasus is *conduplicate;* of Prunus domestica, *convolute;* of Ferns and Cycadaceæ, *circinate*, and so on.

M. Dutrochet calls by the name of *embryo-buds* (fig. 24.) those nodules which are so well known in the bark of the Beech, and some other trees, and which are externally indicated by small tumours of the bark. According to this author such bodies are at first very small and globular, in the tissue of the bark, near its surface; he has found some not larger than a pin's head, and thinks they are born in the parenchymatous tissue. They are at first completely free, and isolated in the bark, have a peculiar bark of their own, which is united with that of the parent tree, but which may in the Cedar be easily distinguished by the direction of its fibres.



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The form of such nodules is variable; sometimes they are rounded, sometimes conical, &c. When in the progress of developement, the woody nodules born in the thickness of the bark, bring their wood in contact with that of the tree which bears them, the intermediate bark disappears, being destroyed by the pressure to which it is subjected, and then the wood of the nodule becomes adherent to the wood of the tree. This adhesion sometimes does not take place for several years. The wood of the nodules is arranged in concentric zones around a common centre, and has both pith and medullary rays; and, however irregular, the form is evidently in all cases a genuine *sphere;* it has all the elements of organisation found in the trunk of the tree, but arranged differently. The side next the wood of the parent tree is thicker than the opposite side, which Dutrochet attributes to its being more immediately in contact with the cambium which nourishes it. In the Cedar of Lebanon the nodules have been seen producing a small branch from the summit. M. Dutrochet regards these nodules as adventitious buds arrested in their formation, and he compares them to the internode of Tamus communis, which forms a tuberous root-like body in that species.

A circumstance to which this physiologist attaches great importance is, that these nodules have an abundance of cambium in the spring, and yet they are not, he says, in communication with the alburnum of the tree; whence he concludes that cambium is elaborated by the bark exclusively. I am not, however, able to reconcile this statement (*Memoires*, i. 311.) with another (p. 304.), that the base of the nodule is "certainement" in adhesion with the wood of the tree.

2. Of its External Modifications.

It has already been stated, that the first direction taken by the stem immediately upon its developement is upwards into the air. While this ascending tendency is by many plants maintained during the whole period of their existence, by others it is departed from at an early age, and a horizontal course is taken instead; while also free communication with light and air is essential to most stems, others remain during all their lives buried under ground, and shun rather than seek the light. From these and other causes, the stems of plants assume a number of different states, to which botanists attach particular terms. It will be most convenient to divide the subject into the varieties of —

1. The *subterranean* stem; and
2. The *aerial* stem.

The SUBTERRANEAN stem was confounded by all the older botanists, as it still is by the vulgar, with the root, to which it bears an external resemblance, but from which it is positively distinguished both by its ascending origin, and by its anatomical structure. (*See* Root.)

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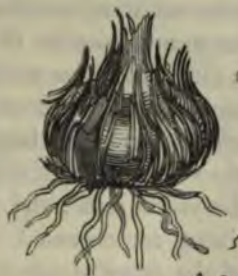

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The following are the varieties which have been distinguished:—

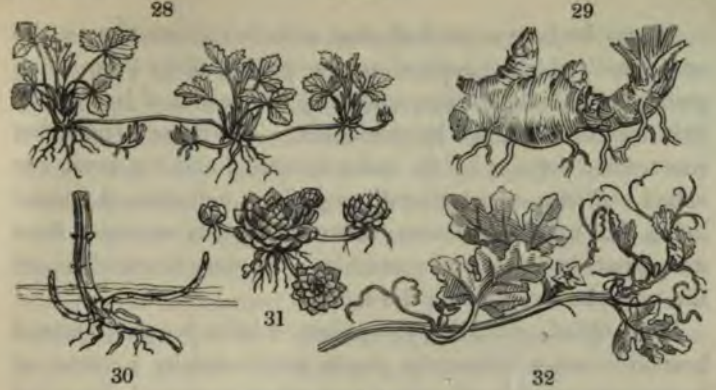
The *Cormus, fig.* 25. (*Lecus* of Du Petit Thouars, *Plateau* of De Candolle), is the dilated base of the stem of Monocotyledonous plants, intervening between the roots and the first buds; and forming the reproductive portion of the stem of such plants when they are not caulescent. It is composed of cellular tissue, traversed by bundles of vessels and pleurenchyma, and has often the form of a flattened disk. The fleshy "root" of the Arum, that of the Crocus and the Colchicum, are all different forms of the cormus. It has been called *bulbotuber* by Ker, and *bulbus solidus* by many others; the last is a contradiction in terms. (*See* Bulb.)

The stems of Palms have by some writers been considered as an extended cormus, and not a true stem, but this seems an extravagant application of the term; or rather an application which reduces the signification of the term to nothing. A cormus is a depressed subterranean stem of a particular kind; the trunk of a Palm is, as far as its external character is concerned, as much a stem as that of an Oak. De Candolle applies the name cormus only to the stems of Cryptogamous plants, and refers to it the *Anabices* of Necker.

The *Tuber*, *fig.* 26. (*Tuberculum* if very small), is an annual thickened subterranean stem, provided at the sides with latent buds, from which new plants are produced the succeeding year, as in the Potato and Arrow-root. A tuber is, in reality, a part of a subterranean stem, excessively enlarged by the developement to an unusual degree of cellular tissue. The usual consequences attendant upon such a state take place; the regular and symmetrical arrangement of the buds is disturbed; the buds themselves are sunk beneath the surface, or half obliterated, and the whole becomes a shapeless mass. Such is not, however, always the case; the enlargement sometimes occurs without being accompanied by much distortion, and the true nature of the tuber stands revealed; this is remarkably the case in the Asparagus Potato. In most, perhaps all tubers, a great quantity of amylaceous matter is deposited, on which account they are frequently found to possess highly nutritive properties.

The *Creeping stem*, *fig.* 27. (*soboles*), is a slender stem, which creeps along horizontally below the surface of the earth, emitting roots and new plants at intervals, as in the Triticum repens. It differs in nothing whatever from the rhizoma, except in being subterranean. This is what many botanists call a creeping *root*. It is one of those provisions of nature by which the barren sands that bound the sea are confined within their limits; most of the plants which cover such soils being provided with subterranean stems of this kind. It is also extremely tenacious of life, the buds at every node being capable of renewing the existence of the individual; hence the almost indestructible properties of the Couch grass, Triticum repens, by the ordinary operations of husbandry: divisions of its creeping stem, by cutting and tearing, producing no other effect than that of calling new individuals into existence as fast as others are destroyed. The term soboles is applied by Link and De Candolle to the sucker of trees and shrubs. (See *Surculus*.)

Of the AERIAL stem, the most remarkable forms are the following: —



The *Runner*, *fig.* 28. (*sarmentum* of Fuchs and Linnæus), is a prostrate filiform stem, forming at its extremity roots and a young plant, which itself gives birth to new runners, as in the Strawberry. Rightly considered, it is a prostrate viviparous scape, that is to say, a scape which produces roots and leaves instead of flowers. It has been called *flagellum* by some modern botanists, but that term properly applies to the trailing shoots of the vine.

The *Sucker*, *fig.* 30. (*surculus*), is a branch which proceeds from the neck of a plant beneath the surface, and becomes erect as soon as it emerges from the earth, immediately producing leaves and branches, and subsequently roots from its base, as in Rosa spinosissima, and many other plants. Link applies the term *soboles* to this form of stem. From this has been distinguished by some botanists the *Stole* (*stolo*), which may be considered the reverse of the sucker, differing in proceeding from the stem above the surface of the earth, into which it afterwards descends and takes root, as in Aster junceus; but there does not appear to be any material distinction between them. Willdenow confines the term *surculus* to the creeping stems of Mosses. By the older botanists a sucker was always understood by the word *stolo*, and *surculus* indicated a vigorous young shoot without branches.

The shoots thrown up from the subterranean part of the stem of Monocotyledonous plants, as the Pineapple for example (the *Adnata*, *Adnascentia*, or *Appendices* of Fuchsius), are of the nature of suckers.

It may be here remarked, that *stolo* has given rise to the name *stool*, which is applied to the parent plant from which young individuals are propagated by the process of *layering*, as it is technically called by gardeners. The branch laid down was termed *propago* by the older botanists, and the layer was called *malleolus*, which literally signifies a hammer; the name being thus applied, because, when the layer is separated from its parent, its lower end resembles a hammer head, of which the new plant represents the handle.

The *Offset*, *fig*. 31. (*propagulum*, Link), is a short lateral branch in some herbaceous plants, terminated by a cluster of leaves, and capable of taking root when separated from the mother plant, as in Sempervivum. It differs very little from the runner.

The *Rootstock*, fig. 29. (*rhizoma*), is a prostrate thickened rooting stem, which yearly produces young branches or plants. It is chiefly found in Iridaceæ and epiphytous Orchidaceæ, and is often called *caudex repens*. The old botanists called it *cervix*, — a name now forgotten.

The *Vine*, *fig*. 32. (*viticula*, Fuchs.), is a stem which trails along the ground without rooting, or entangles itself with other plants, to which it adheres by means of its tendrils, as the Cucumber and the Vine. This term is now rarely employed. De Candolle refers it to the runner or sarmentum; but it is essentially distinct from that form of stem, because it does not root.

The *Pseudobulb* is an enlarged aerial stem, resembling a tuber, from which it scarcely differs, except in its being formed above ground, in having an epidermis that is often extremely hard, and in retaining upon its surface the scars of leaves which it once bore. This is only known in Orchidaceous plants, in which it is very common.

The term *stem* (*caulis*) is generally applied to the ascending caudex of herbaceous plants or shrubs, and not to trees, in which the word *trunk* is employed to indicate their main stem; sometimes, however, this is called *caulis arboreus*. From the *caulis*, Linnæus, following the older botanists, distinguished the *culmus* or *straw*, which is the stem of Grasses; and De Candolle has further adopted the name *Calamus* for all fistular simple stems without articulations, as those of Rushes; but neither of these differ in any material degree from common stems, and the employment of either term is superfluous. This has already been remarked with respect to culmus by Link, who very justly inquires (Linnæa, ii. 235.) "cur Graminibus caulem denegares et culmum diceres?"

If a plant is apparently destitute of an aerial stem, it is technically called *stemless* (*acaulis*), a term which must not however be understood to be exact, because it is, from the nature of things, impossible that any plant can exist without a stem in a greater or less degree of developement. All that the term *acaulis* really means, is that the stem is very short.

3. Of its Internal Modifications.

The internal structure of the stems of Flowering plants, is subject to two principal and to several subordinate modifications. The former are well illustrated by such plants as the Oak and the Cane, specimens of which can be easily obtained for comparison. A transverse slice of the former exhibits a central cellular substance or *pith*, an external cellular and fibrous ring or *bark*, an intermediate *woody* mass, and certain fine lines radiating from the pith to the bark, through the wood, and called *medullary rays;* this is called EXOGENOUS structure. In the Cane, on the contrary, neither bark, nor pith, nor wood, nor medullary rays, are distinguishable; but the transverse section exhibits a larger number of holes irregularly arranged, and caused by the section of bothrenchymatous and vascular tissue, and the mass of woody and cellular substance in which they lie imbedded. This kind of structure is named ENDOGENOUS.

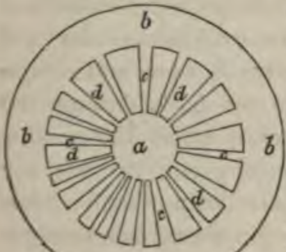
In both cases there is a *cellular* and *vascular system* distinct from each other; it is only by a diversity in their respective arrangement that the differences above described are caused. In explaining in detail the peculiar structure of Exogenous and Endogenous stems, it will be more convenient to consider them with reference to those two systems, than to follow the usual method of leaving the fact of there being two distinct systems out of consideration.

§ 1. *Of the* Exogenous *Structure.*

33

The *cellular* system in an Exogenous stem chiefly occupies the centre and the circumference, which are connected by thin vertical plates of the same nature as themselves. The central part (*a*, *fig.* 34.) is the *pith*, that of the circumference (*b*) is the *bark*, and the connecting vertical plates (*c*) are *medullary rays*.

fig. 34.



The *pith* is a cylindrical or angular column of cellular tissue, arising at the point of separation between the root and stem and terminating at the leaf-buds, with all of which, whether they are lateral or terminal, it is in direct communication. Its tissue, when cut through, almost always exhibits an hexagonal character, and is frequently larger than in any other part. When newly formed, it is green, and filled with fluid; but its colour gradually disappears as it dries up, and it finally becomes colourless. After this it undergoes no further change, unless by the deposition in it, in course of time, of some of the peculiar secretions of the species to which it belongs. It has been contended, indeed, by some physiologists, that it is gradually pressed upon by the surrounding part of the vascular system, until it is either much reduced in diameter or wholly disappears; and in proof of this assertion, the Elder has been referred to, in which the pith is very large in the young shoots, and very small in the old trunks. Those, however, who entertain this opinion, seem not to consider that the diameter of the pith of all trees is different in different shoots, according to the age of those shoots; — that in the first that arises after germination, the pith is a mere thread, or at least of very small dimensions — that in the shoots of the succeeding year it becomes larger — and that its dimensions increase in proportion to the general rapidity of developement of the vegetable system: the pith, therefore, in the first-formed shoots, in which it is so small compared with that in the branches of subsequent years, is not small because of the pressure of surrounding parts; it never was any larger.

The pith is always, when first forming, a uniform compact mass, connected without interruption in any part; but the vascular system sometimes developing more rapidly than itself, it occasionally happens that it is either torn or divided into irregular cavities, as in the Horse Chestnut, the Rice-paper plant, and many others; or that it is so much lacerated as to lose all resemblance to its original state, and to remain in the shape of ragged fragments adhering to the inside of the vascular system: this is what happens in Umbelliferous and other fistular-stemmed plants.

Sometimes the pith is much more compact at the nodes than in the internodes, as in the Ash; whence an idea has arisen that it is actually interrupted at those places: this is, however, a mistake; for in general there is no interruption of continuity, but a mere alteration in compactness. It does however sometimes happen, that the pith takes a large developement at the nodes, so as to cut off the vascular system of the internodes into almost distinct parts. This occurs in what are called articulated stems, as in Piper, Viscum, &c., and in the Vine when young. Dutrochet regards such cases as evidence that each internode is an independent creation in the beginning, and that it is only after having been growing for a period of time, varying in different cases, that the internodes become connected by woody formations.

It seldom happens that any part of the vascular system intermixes with the pith, which is usually composed of cellular tissue exclusively; but in Ferula and the Marvel of Peru, it has been proved by Mirbel and De Candolle, that bundles of woody fibre are intermixed; in Nepenthes there is a considerable quantity of spiral vessels scattered among the cellular tissue of the same part; and many other cases of a similar kind are now known. In Nyctaginaceæ generally, in Piperaceæ, Cycadaceæ, Chloranthaceæ, &c., this occurs, and has been made by Professor Schultz the character of a large division in his Natural System of Botany, called by him *Synorgana dichorganoidea;* but such cases may be found in Loranthus, and are not uniform in the orders quoted: in Boerhaavia repanda, for example, the pith contains no bundles of vascular tissue, but is *filled with fistulæ containing very soft, lax, spheroidal, cellular tissue, surrounded by smaller, harder, and more cubical tissue, which passes into the medullary rays;* a most curious organisation.

The *Bark* is the coating of the stem immediately above the wood, to which it forms a sort of sheath, and from which it is separable without difficulty at certain seasons. But, although it appears as an independent formation, it is, in reality, organically connected with the wood by the processes of cellular tissue, which, under the name of medullary rays, pass through the wood, and lose themselves in the thickness of the bark. Formerly bark was distinguished into *cortical* or *cellular integument,* under which name was comprehended the whole of the external parenchymatous part, and *liber* or *inner bark,* a name used to denominate the fibrous woody portion lying next the alburnum. But it is necessary to look at the organisation of the bark with more precision, if we are to understand all the peculiarities found in its many modifications. It appears to me that the observations of Mohl are the best and most complete which have hitherto been made upon this very important subject: they, and many more of considerable value, by Dutrochet, Link, and others, render a peculiar nomenclature for the parts of the bark indispensable; so many false or indefinite ideas are there which attach to the older terms. Bark may be described anatomically as composed of four separate parts:—1. The *Epidermis*, which is continuous with that of the leaves, resembling what is found upon their veins, like it composed of cells a little lengthened, and rarely furnished with stomates; it often bears hairs. 2. The *Epiphlœum* of Link, *Phlœum* or *Peridermis* of Mohl, consisting of several layers of thin-sided tubular cells, rarely coloured green. 3. The *Mesophlœum* of Link, or *cellular integument* of others, composed of cells usually green, and placed in a different direction from those of the epiphlœum; sometimes, as in Quercus Suber, containing cellular concretions. 4. The *Endophlœum* or *Liber*, of which a part is cellular and a part composed of woody tubes. These are modified differently in different trees; and the appearances of Cork in many plants, of thin white lamellæ or hard plates in others, are so produced. Usually each stratum has a separate growth, which takes place by the addition of new matter to its interior; thus the endophlœum, or liber, grows next the alburnum, the mesophlœum next the endophlœum, and the epiphlœum next the mesophlœum; the epidermis does not grow at all. Such growth is often indicated by concentric circles, which correspond in each layer with the zones of wood.*

When the substance called *Cork* is formed, the epiphlœum consists of polyedral cells, which multiply with unusual rapidity and in great quantities. It does not appear to have any communication by lateral passages with the interior of the plant; although Dutrochet represents them to exist in Ulmus suberosa, where I cannot find them. After a certain age, it exfoliates in the Cork Tree, but in such plants as Acer campestre, Ulmus, &c., it is simply rent and thrown off piecemeal. In the Birch, the Cherry, and similar trees, it forms annually only a few layers of tabular cellular tissue, *arranged in transverse rows*, which separate at a certain age into thin silvery lamellæ: these have been improperly confounded with the epidermis. The cause of the separation of the lamellæ of the epiphlœum of the Birch is found in the developement, between the lamellæ, of a layer of thin-sided cells, less compactly arranged, and easily separating into a fine powder when disturbed.

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* But, according to Decaisne (*Comptes rendus*, v. 393.), in Menispermaceæ the liber is only formed for the first year, and is afterwards covered over by new wood; and consequently is found near the centre round the pith, and not at the circumference.

As strata of cellular tissue, in a peculiar state, may form between the lamellæ of the Birch and other such trees, so may it in other parts of the bark. This causes the sloughing of hard thin plates from the bark of the Plane tree; which Mohl explains thus:—Up to its eighth or tenth year, the bark of the Plane tree is like that of the Beech; at that period there forms in different parts of the liber a stratum of tabular cells, in all respects analogous to those of the epiphlœum. This new epiphlœum is not exactly parallel with that of older date, which exists at the surface of the bark, and cuts off an exterior portion, which then dies and drops off in the manner with which we are all familiar. The scales produced by this formation of epiphlœum inside the liber or mesophlœum Mohl calls *Rhytidoma*, from ῥυτις, a wrinkle. (*Ann. des Sciences*, N. S. IX. 290.)

In some plants the epiphlœum forms regular strata, parallel with the axis of the stem, and afterwards separates into strips analogous to those of the liber, as in the Juniper, Callistemon lophanthus, &c. In others, a portion of the liber is really thrown off annually, as in the Vine, the Honeysuckle, &c.

Hence in exogenous trees, the thickness of the bark is annually diminished by one of two causes; either by an exfoliation of the external and dead portions of the epiphlœum only, or by a formation of a second epiphlœum, or false cork, among the liber, the result of which is the throwing off the parts of the bark lying over it as soon as they die.

So long as the parts of the bark remain alive, they give way to the expansion of the wood within it, by adding new tissue to themselves, as has been already stated: but when they die, they are necessarily torn into clefts, rents, or ribands, as we find in the trunks of trees.

It will have been seen that the only part of the bark in which woody tissue occurs is the endophlœum. Here it is often very abundant, and exceedingly tough and thick-sided; in consequence of which it is of great value for many useful purposes. When freed from the cellular tissue adhering to it, it is often manufactured into cordage, especially in trees and shrubs of the natural order Malvaceæ. The Russia mats of commerce are manufactured from the thin laminæ into which the endophlœum of Tilia europæa readily separates. The Lace bark of Jamaica, remarkable for its beautiful lace-like appearance when gently pulled laterally, and for its great toughness, whence it is often twisted into whip-lashes, is the laminated liber of Lagetta lintearia.

When stems are old, the bark usually bears but a small proportion in thickness to the wood; yet in some plants its dimensions are of a magnitude that is very remarkable. For instance, specimens of Abies Douglasii have been brought to Europe twelve inches thick, and these are said not to be of the largest size.

Air cells and Vasa propria are exceedingly common in the bark, but there is no authenticated instance of any spiral or other vessels having been found in it; except in Nepenthes, in which they occur in almost every part, and exist in no inconsiderable numbers in the bark.

Beneath the bark, and above the wood, is interposed in the spring a mucous viscid layer, which, when highly magnified, is found to contain numerous minute transparent granules, and to exhibit faint traces of a delicate cellular organisation. This secretion is named the CAMBIUM, and appears to be exuded both by the bark and wood, certainly by the latter; but Dutrochet says only by the former, founding his opinion upon the presence of cambium in bark nodules, which, he says, have no communication with the wood of the parent tree; see page 80.

The cellular system of the pith and that of the bark are, in the embryo and youngest shoots, in contact; but the woody system, as it forms, gradually interposes between them, till after a few weeks they are distinctly separated, and in very aged trunks are sometimes divided by a space of several feet; that is to say, by half the diameter of the wood. But whatever may be the distance between them, a horizontal communication of the most perfect kind continues to be maintained. When the woody system is first insinuated into the cellular system, dividing the pith and cortical integument, it does not completely separate them, but pushes aside a quantity of cellular tissue, pressing it tightly into thin vertical radiating plates: as the woody system extends, these plates increase outwardly, continuing to maintain the connection between the centre and the circumference. Botanists call them *medullary rays* (or *plates*); and carpenters, the *silver grain.* They are composed of muriform cellular tissue (Plate I. fig. 7.), often not consisting of more than a single layer of cellules; but sometimes, as in Aristolochias, the number of layers is very considerable. In horizontal sections of an Exogenous stem, they are seen as fine lines radiating from the centre to the circumference; in longitudional sections they produce that glancing satiny lustre which is in all discoverable, and which gives to some, such as the Plane and the Sycamore, a character of remarkable beauty.

No vascular tissue is ever found in the medullary rays, unless those curious plates described by Griffith in the wood of Phytocrene gigantea, in which vessels exist, should prove to belong to the medullary system.

The *vascular* system in an Exogenous stem is confined to the space between the pith and the bark, where it chiefly consists of ducts, and pitted or woody tissue collected into compact wedge-shaped vertical plates, *fig.* 34. the edges of which rest on the pith and bark, and the sides of which are in contact with the medullary rays.

That portion of the vascular system which is first generated is in immediate contact with the pith, to which it forms a complete sheath, interrupted only by the passage of the medullary rays through it. It consists of spiral vessels and woody tissue intermixed, and forms an exceedingly thin layer, called the *medullary sheath.* This is the only part of the vascular system of the stem in which spiral vessels are ordinarily found; the whole of the vessels subsequently deposited over the medullary sheath being bothrenchymatous tissue, with a few exceptions. The medullary sheath establishes a connection between the axis and all its appendages, the veins of leaves, flowers, and fruits, being in all cases prolongations of it. It has been remarked by Senebier, and since by De Candolle, that it preserves a green colour even in old trunks, which proves that it still continues to retain its vitality when that of the surrounding parts has ceased.

The vascular system of a stem one year old consists of a zone of wood lying between the pith and the bark, lined in the inside by the medullary sheath, and separated into wedge-shaped vertical plates by the medullary rays that pass through it. All that part of the first zone which is on the outside of the medullary sheath is composed of woody tissue and vessels intermixed in no apparent order; but the vessels are generally either in greater abundance next the medullary sheath, or confined to that side of the zone, and the woody tissue alone forms a compact mass on the outside. The second year another zone is formed on the outside of the first, with which it agrees exactly in structure, except that there is no medullary sheath; the third year a third zone is formed on the outside of the second, in all respects like it; and so on, one zone being deposited every year as long as the plant continues to live. As each new zone is formed over that of the previous year, the latter undergoes no alteration of structure when once formed: wood is not subject to distension by a force beneath it, as the bark is; but, whatever the first arrangement or direction of its tissue may be, such they remain to the end of its life. The formation of the wood is, therefore, the reverse of that of the bark; the latter increasing by addition to the inside of its strata, the former by successive deposits upon its outside. It is for this reason that stems of this kind are called Exogenous (from two Greek words, signifying to grow outwardly). According to Dutrochet, each zone of wood is in these plants separated from its neighbour by a layer of cellular tissue, forming part of the system of the pith and bark; but although this is true in certain plants, such as arborescent nettles and others, it is by no means a general law.

After wood has arrived at the age of a few years, or sometimes even sooner, it acquires a colour different from that which it possessed when first deposited, becoming what is called *heart-wood*, or *duramen*. For instance, in the beech it becomes light brown, in the oak deep brown, in Brazil wood and Guaiacum green, and in ebony black. In all these it was originally colourless, and owes its different tints to matter deposited gradually in all parts of the tissue; as may be easily proved by throwing a piece of heart-wood into nitric acid, or some other solvent, when the colouring matter is discharged, and the tissue recovers its original colourless character. That part of the wood in which no colouring matter is yet deposited, and consequently that which, being last formed, is interposed between the bark and duramen, is called *alburnum*. The distinction between these is physiologically important, as will hereafter be explained.

Each zone of the vascular system of an Exogenous stem being the result of a single year's growth, it should follow that, to count the zones apparent in a transverse section is sufficient to determine the age of the individual under examination; and further, that, as there is not much difference in the average depth of the zones in very old trees, a certain rate of growth being ascertained to be peculiar to particular species, the examination of a mere fragment of a tree, the diameter of which is known, should suffice to enable the botanist to judge with considerable accuracy of the age of the individual to which it belonged. It is true, indeed, that the zones become less and less deep as a tree advances in age; that in cold seasons, or after transplantation, or in consequence of any causes that may have impeded its growth, the formation of wood is so imperfect as scarcely to form a perceptible zone: yet De Candolle has endeavoured to show in an able paper, *Sur la Longévité des Arbres*, that the general accuracy of calculations is not much affected by such accidents; occasional interruptions to growth being scarcely appreciable in the average of many years. This is possibly true in European trees, and in those of other cold or temperate regions in which the seasons are distinctly marked; in such the zones are not only separated with tolerable precision, but do not vary much in annual dimensions. But in many hot countries the difference between the growing season and that of rest, if any occur, is so small, that the zones are as it were confounded, and the observer finds himself incapable of distinguishing with exactness the formation of one year from that of another. In the wood of Guaiacum, Phlomis fruticosa, Metrosideros polymorpha, and many other Myrtaceæ, for instance, the zones are extremely indistinct; in some Bauhinias they are formed with great irregularity; and in Stauntonia latifolia, some kinds of Ficus, certain species of Aristolochia, as A. labiosa, and many other plants, they are so confounded, that there is not the slightest trace of annual separation. It is also to be remarked, that in Zamias we seldom find more than two or three zones of wood, whatever may be the age of the individual; and yet it appears from Ecklon's observations, that a Zamia, with a trunk only four or five feet high, can scarcely be less than two or three hundred years old. (*Lehm. Pugill.* vi.)*

With regard to judging of the age of a tree by the inspection of a fragment, the diameter of the stem being known, a little reflection will show that this is to be done with great caution, and that it is liable to excessive error. If, indeed, the zones upon both sides of a tree were always of the same, or nearly the same, thickness, much error would, perhaps, not attend such an investigation; but it happens that, from various causes, there is often a great difference between the growth of the two sides, and consequently, that a fragment taken from either side must necessarily lead to the falsest inferences. For example, I have now before me four specimens of wood, taken almost at hazard from among a fine collection, for which I am indebted to the munificence of the East India Company. The measurements of either side, and their age, as indicated by the number of zones they comprehend, are as follows: —

	Diameter of		Total.	Real Age, or No. of Zones.
	Side A.	Side B.		
Benthamia fragifera -	9 lines.	36 lines.	45 lines.	40
Pyrus foliolosa - -	8 lines.	22 lines.	30 lines.	36
Magnolia insignis - -	11 lines.	20 lines.	31 lines.	17
Alnus napalensis - -	11 lines.	23 lines.	34 lines.	8

Now, in the first of these cases, suppose that a portion of the side A. were examined, the observer would find that each zone is 0·225 of a line deep; and, as the whole diameter of the stem is 45 lines, he would estimate the side he examined to be 22·5 lines deep; consequently, he would arrive, by calculation, at the conclusion, that, as his plant was one year growing 0·225 of a line, it would be a hundred years in growing 22·5 lines, while, in fact, it has been only forty years. And so of the rest.

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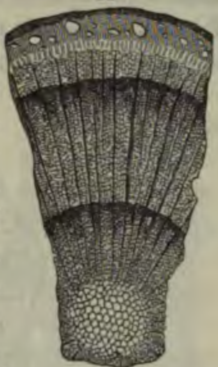
* According to Decaisne (*Comptes rendus*, v. 393.) the zones of wood in Menispermaceæ each result from the growth of several years.

When we hear of the Baobab trees of Senegal being 5150 years old, as computed by Adanson, and the Taxodium distichum still more aged, according to the ingenious calculations of Alphonse De Candolle, it is impossible to avoid suspecting that some such error as that just explained has vitiated their conclusions.

To the characters above assigned to the stem of Exogenous plants there are several remarkable exceptions, some of which have been described by botanists; others are mentioned now for the first time.

Mirbel has noticed the unusual structure of Calycanthus (*Annales des Sciences*, vol. xiv.), in the bark of which, at equal distances, are found four minute extremely eccentrical woody axes, the principal diameter of which is inwards; that is to say, next the wood. The existence of this structure, noticed by the discoverer only in C. floridus, I have since ascertained in all the other species, and also in Chimonanthus. Gaudichaud attempts to explain this curious mode of growth upon the supposition that each leaf forms three fascicles of woody matter, whereof the central is the most powerful, and produces the mass of the stem; and the lateral ones, which are much weaker, give origin to the accessory axes; — and he states, that in climbing Sapindaceous plants the same phenomenon occurs, only to a far greater extent. He represents that in those cases the fibres of each leafstalk separate into three or four principal branches, each of which applies itself to one of the internal woody axes of the stem, which, in time, consists of from four to eight distinct axes, the central being larger than the others, and each having its own cortical integument. The fact is curious, but I doubt whether the explanation is just. (*Arch. de Bot.*, ii. 492.)

35

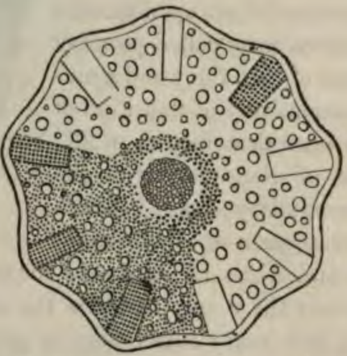


In Coniferous wood (*fig.* 35.) there is scarcely any mixture of bothrenchyma among woody tissue, as in other exogenous plants; in consequence of which a cross section exhibits none of those open mouths which give what is vulgarly called porosity to wood. Instead of this, the wood generally consists exclusively of that kind of tissue which has been described at p. 25., under the name of glandular, with the exception of the medullary sheath, in which spiral vessels are present in small numbers. The Yew and Abies Douglasii are the principal exceptions: in the former the woody tissue is the same as that of other Coniferæ; but many tubes have a great quantity of little fibres lying obliquely across them at nearly equal distances, — sometimes arranged with considerable regularity, — sometimes disturbed as it were, — so that the transverse fibres, although they retain their obliquity, are not parallel, — and sometimes, but more rarely, so regular as to give to the tubes of woody tissue the appearance of spiral vessels, the coils of which are separated by considerable intervals. The latter only is represented by Kieser, at his tab. xxi. fig. 103, 104.; but the former is by far the most common appearance.

In Cycadaceæ the vascular system is destitute of vessels, as in Coniferæ; their place being supplied by such bothrenchyma as has been already described at p. 22. But the zones of wood are separated by a layer of cellular substance resembling that of the pith, and often as thick as the zones themselves, while the pith itself is filled with bundles of fibro-vascular tissue. This structure is represented by Adolphe Brongniart, in the 16th volume of the Annales des Sciences.

Mr. Griffith has beautifully illustrated the structure of a plant called Phytocrene (*fig.* 36.), in Wallich's Plantæ Asiaticæ, vol. iii. t. 216. In this curious production the wood consists of plates containing vessels and woody tissue, having no connection with each other, and separated at very considerable intervals by a large mass of prosenchymatous cellular tissue filled with vasiform tissue, and representing medullary rays.* When the stem is dry, the woody plates separate from the other tissue, in which they finally lie loose.

36



In Nepenthes distillatoria the pith contains a great quantity of spiral vessels; the place of the medullary sheath is occupied by a deep and dense layer of woody tissue, in which no vessels, or scarcely any, are discoverable; there are no medullary rays; the wood has no concentric zones; between the bark and the wood is interposed a thick layer of cellular tissue, in which an immense quantity of very large spiral vessels is formed; on the outside of this layer is a thinner coating of woody tissue, containing some very minute spiral vessels; and, finally, the whole is enclosed in a cellular integument, also containing spiral vessels of small size. In this singular plant the outer layers are, it is to be presumed, liber and epidermis; and the cellular deposit between the former and the wood is analogous to cambium in an organised state, belonging equally to the wood and the bark. What is so exceedingly remarkable is the complete intermixture of the vascular and cellular systems, so that limits no longer exist between the two.

I have a specimen of the twisted compressed stem of a Bauhinia from Colombia (*fig.* 37.), in which there are no concentric circles, properly so called; but in which there are certain irregular flexuous zones, consisting of a layer of cellular tissue coated by a stratum of woody tissue, enclosing, at irregular distances from the centre, very unequal portions of the vascular system. The pith is exceedingly excentrical; and the medullary rays, which are imperfectly formed, do not all radiate from the pith, but on the thickest side form curves passing from one side of the stem to the other, their concavities turned towards the pith.

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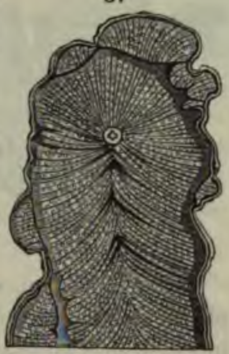
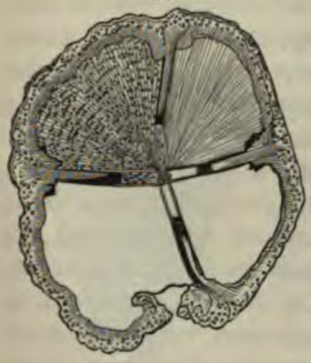
* It will be seen that the view I now take of the analogies of the parts in the trunk of Phytocrene is very different from that in the first edition of this work.

37



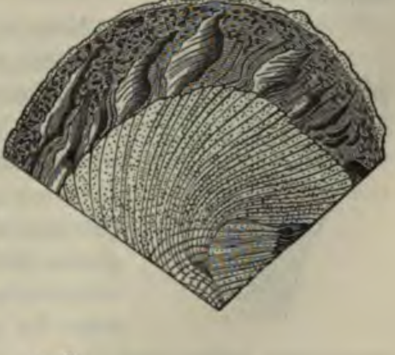
In the stem of a Bignonia in my possession, from Colombia (*fig.* 38.), the vascular system is divided into four nearly equal parts, by four short thick plates radiating from the pith, and consisting of woody tissue, with a very few vessels. These plates are not more than one third the depth of the wood; so that between their back and the bark there is a considerable vacancy, by which the four divisions of the vascular system are separated. This vacancy is nearly filled with bark, which projects into the cavity.

38



In Stauntonia latifolia (*fig.* 39.), which has a twining stem, there are no concentric circles, and the medullary rays are curved, part from right to left, and part from left to right, diverging at one point and converging at another: the bark is pierced with extensive longitudinal perforations.

39



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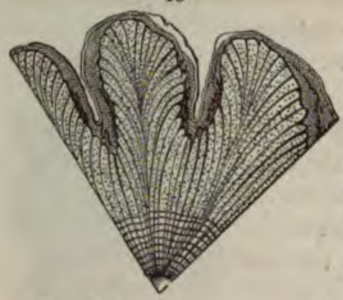
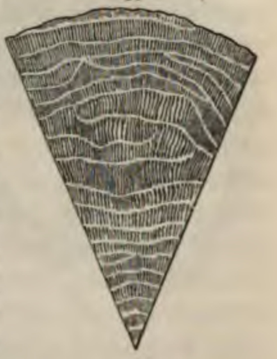


In Euonymus tingens (*fig.* 40.) the vessels near the centre of the stem are arranged in concentric interrupted circles, but towards the bark there is no trace of such circles; the surface of the stem is deeply cut into lobes parallel with the stem, and the vessels are all confounded in an uniform mass.

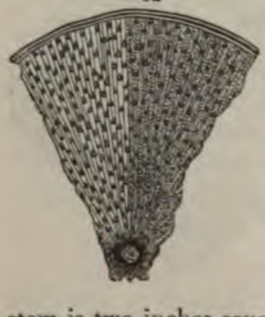
Gaudichaud represents the stem of some Malpighiaceous plants to be in like manner divided into a number of regular lobes, which however, actually reach the axis; and, in consequence of the twining habit of the stem, are twisted into the appearance of a cable externally.

41



In Menispermum laurifolium (*fig.* 41.) the concentric lines evidently belong to the medullary system; they are extremely interrupted and unequal, often only half encircling the stem, or even less, and they anastomose in various ways; the medullary rays are unusually large, and lie across the wood like parallel bars; and, finally, the plates of which the wood consists each contains but one vessel, which is situated at the external edge of the plate.

42



None of the anomalous forms of Exogenous stems are, however, more remarkable than an unknown Burmese tree (*fig.* 42.), for a specimen of which I am indebted to Dr. Wallich. In a section of this, the general appearance is so much that of an Endogenous stem, that without an attentive examination it might be actually mistaken for one. The diameter of this stem is two inches seven lines; it is nearly perfectly circular, and has a very thin but distinct bark, with a central pith surrounded by very compact woody tissue. There are neither zones nor medullary rays; but the vascular system consists of an uniform mass of vessels and woody tissue, disposed with great symmetry, and of the same degree of compactness at the circumference as in the centre. Amongst this wood are interspersed, at the distance of about half a line, with great regularity, passages containing loose cellular tissue. These passages are convex at the back and rather concave in front, run parallel with the vessels, and do not seem to have any kind of communication with each other. They, no doubt, represent the medullary rays of the cellular system of this highly curious plant. It must be remarked, that the resemblance borne by this stem to that of an Endogenous plant is more apparent than real; for whilst, in the latter, the vascular system is separated into bundles surrounded by the cellular system, in this, on the contrary, the cellular system consists of tubular passages, surrounded by masses of the vascular system.

It will be observed that, in all those cases of irregular developement, the part next the centre is but little affected; and such seems to be the general rule. In the Penny Cyclopædia, article Exogens, there are figures of several cases of structure still more anomalous than the preceding, with the woody matter contorted excessively; but even in them the centre is in the normal condition of exogenous wood.

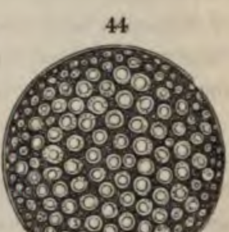
Such examples show the student that it is neither medullary rays nor concentric zones in the wood that are the certain indications of Exogenous growth, both the one and the other being sometimes absent; but that the presence of a central pith, and a greater degree of hardness in the wood next the centre, than in the circumference, are the signs from which alone any absolute evidence can be derived.

§ 2. *Of the* Endogenous *Structure.*

43

Plants of an arborescent habit having this structure being almost exclusively extra-European, and most of them natives only of the tropics, botanists have had much fewer opportunities of examining them, and, consequently, our knowledge concerning them is more limited. Nevertheless, the investigations of Mohl and others have thrown great light upon their real organisation.

44



In Endogenous plants the vascular and cellular systems are as distinct as in Exogenous, but they are differently arranged. The cellular system, instead of being distinguishable into pith, bark, and medullary rays, is a uniform mass, in which the vascular system lies imbedded in the form of thick fibres, seldom having any tendency to collect into zones or wedges resembling wood. The fibrous bundles consist of woody tissue, enclosing spiral or other vessels.

The following is an explanation of the opinions generally entertained concerning the formation of an Endogenous stem. Its diameter is supposed to be increased by the constant addition of fibrous bundles to the centre, whence the name; those bundles displace such as are previously formed, pushing them outwards; so that the centre, being always most newly formed, is the softest; and the outside, being older, and being gradually rendered more and more compact by the pressure exercised upon the bundles lying next it by those forming in the centre, is the hardest. In Endogenous plants that attain a considerable age, such as many Palms, this operation goes on till the outside becomes sometimes hard enough to resist the blow of a hatchet. It does not, however, appear that each successive bundle of fibres passes exactly down the centre, or that there is even much regularity in the manner in which they are arranged in that part: it is only certain that it is about the centre that they descend, and that on the outside, below the growing point, no new formation takes place from the circumference. This appears from the manner in which the bundles cross and interlace one another, as is shown in the figure of Pandanus odoratissimus given by De Candolle in his Organographie (tab. vi.), or still more clearly in the lax tissue of the inside of the stems of Dracæna Draco.

The investigations of Mohl appear, however, to show that this view of the structure of Endogens requires some modification. According to this observer, every one of the woody bundles of a Palm stem originates in the leaves, and is at first directed towards the centre; arrived there, it follows the course of the stem for some distance, and then turns outward again, finally losing itself in the cortical integument. In the course of their downward descent, the woody bundles gradually separate into threads, till at last the vascular system, which for a long time formed an essential part of each of them, disappears, and there is nothing left but woody tissue. In this view of the growth of Endogens, the trunk of such plants must consist of a series of arcs directed from above inwards, and then from within outwards; and consequently the woody bundles of such plants, instead of being parallel with each other, must perpetually intersect each other. There are, however, some difficulties in the way of this theory, which we do not find adverted to by its author. If Mohl's view of the structure of Endogens be correct, they must after a time lose the power of growing, in consequence of the whole of the lower part of their stems being choked up by the multitude of descending woody bundles. Is this the case? The lower part of their bark, too, must be much harder, that is, much more filled with woody bundles, than the upper. Is that the fact? The hardness of the exterior of Palm stems cannot be owing to the pressure of new matter from within outwards, but to some cause analogous to the formation of heartwood in Exogens. Is there any proof that such a cause is in operation? These inquiries have been partially answered by Mr. George Gardner, from observations made by him in Brazil. He made a vertical section of a Palm tree four inches in circumference, and he was able plainly to trace woody bundles proceeding from the base of the leaves to the centre of the stem, at an angle of 18°; they then turned downwards and outwards to within a few lines of the external cortical part of the stem, running parallel with its axis. The distance between the ends of the arcs was about two and a half feet. He adds, that the wood of Palm trees is much harder at the bottom than in any other part of the stem, the inhabitants of tropical climates using only this part for economical purposes. (*Taylor's Magazine*, xi. 553.)

The epidermis of an Endogenous stem seems capable of very little distension. In many plants of this kind the diameter of the stem is the same, or not very widely different, at the period when it is first formed, and when it has arrived at its greatest age: Palms are, in particular, an instance of this; whence the cylindrical form that is so common in them. That the increase in their diameter is really inconsiderable, is proved in a curious, and at the same time very conclusive, manner, by the circumstance of gigantic woody climbing plants sometimes coiling round such stems, and retaining them in their embrace for many years, without the stem thus tightly wound round indicating in the slightest manner, by swelling or otherwise, that such ligatures inconvenience it. A specimen illustrative of this is preserved in the Museum of Natural History at Paris, and has been figured, both by Mirbel in his *Elémens* (tab. xix.), and De Candolle in his *Organographie* (tab. iv.). We know from the effect of the common Bindweed upon the Exogens of our hedges, that the embrace of a twining plant is, in a single year, destructive of the life of every thing that increases in diameter; or at least produces, above the strangled part, extensive swellings, which end in death.

It is, however, certain that other Endogens do increase extensively in diameter up to a certain point; sometimes this is effected with great rapidity; and the horizontal growth once stopped appears never to be renewed: thus, in the Bamboo, stems are sometimes found as much as two feet in circumference, which were originally not more than half an inch in diameter. Others would seem to have an unlimited power of distension: in the Dracænas, called in French colonies in Africa Bois-chandelles, the first shoot from the ground is a turio (sucker), an inch in diameter, and perhaps fifteen feet high; but in time it distends so much that sometimes two men can scarcely embrace it in their extended arms. (*Thouars, Essais*, p. 3.)

As Endogenous stems contain no concentric zones, there is nothing in their internal structure to indicate their age; but in the opinion of some botanists, there are sometimes external characters which will afford sufficient evidence of it. It is said that the number of external rings which indicate the fall of leaves from the trunk of the Palm tribe coincides with the number of years that the individual has lived. There is, however, no proof of this at present; such statements must therefore be received with caution. It may further be remarked, with reference to this subject, that in many Palms these rings disappear after a certain number of years.

In arborescent Endogens it usually happens that only one terminal leaf-bud developes; and in such cases the stem is cylindrical, or very nearly so, as in Palms. If two terminal leaf-buds constantly develope, the stem becomes dichotomous, but the branches are all cylindrical, as in Pandanus and the Doom Palms of Egypt; but if axillary leaf-buds are regularly developed, as in the Asparagus, Dracæna Draco, or in arborescent grasses, then the conical form which prevails in Exogens exists in Endogens also.

In Endogens there are but few important anomalies in structure; and of these the most striking, namely that of Grasses, is more peculiar than anomalous. Yucca appears, from a figure of Meneghini (*Ricerche sulla Struttura del Caule nelle Piante Monocotyledoni*, t. ix. f. 1. c.), to arrange its woody bundles in concentric layers when old; Smilax has a stem strictly endogenous, and a root which approaches in structure the stem (not root) of Exogens; and, in the article Endogens, in the Penny Cyclopædia, I have shown that the stem of Barbacenia is composed of roots of an endogenous nature, held together by the adhesion of their cortical integument, and that of a very slender central true stem on which they are moulded. In Grasses the stem is hollow except at the nodes, where transverse partitions intercept the cavity, dividing it into many cells. In the Bamboo these cells and partitions are so large that, as is well known, lengths of that plant are used as cases to contain papers. But if the gradual developement of a grass be attentively observed, it will be found that the stem is originally solid; that it becomes hollow in consequence of its increasing in diameter more rapidly than new tissue can be formed; so that its deviation from the ordinary characters of Endogenous structure is much less considerable than it seems to be at first sight.

According to Mohl, the structure of an Exogenous and an Endogenous stem, during the first year of their growth, is altogether the same; but in the second year the wood and the liber of the former separate, and new matter is then interposed, while, on the contrary, in Endogens no such separation occurs, and consequently the newly-formed matter of the stem is forced towards the centre, through which it passes, with a constant tendency, however, to reach the outside. I confess, however, I do not perceive this analogy; on the contrary, if we compare the new shoot of an Asparagus and that of an Elder-bush, the difference between them will be too great to be thus explained away. M. Dutrochet thinks that in the globular rhizoma of Tamus an argument may be found to show the identity of Exogens and Endogens *in* the first period of their growth; and this may, perhaps, be admitted; but it is equally evident, from the same example, that they become entirely different immediately *after* the first period. Nor, indeed, is the anatomy of the woody tissue, which constitutes the ligneous wedges of Exogens, the same as that which forms the woody bundles of Endogens. In the latter each woody bundle is, when divided transversely, described by Mohl as consisting of the following parts (fig. 45.):

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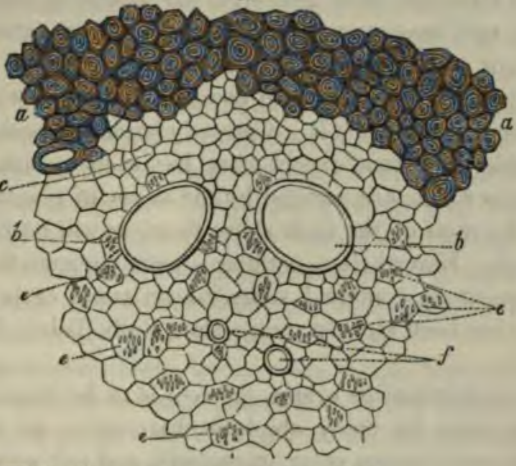

a. Thick-sided woody tissue (*cellulæ libri*).
b. Bothrenchyma (*vasa porosa*).
c. Thin-sided parenchyma (*vasa propria*).
e. A variety of bothrenchymatous tissue (*cellulæ ligni punctatæ*).
f. Spiral vessels.

But this is quite unlike the anatomy of the smaller portions of woody tissue in Exogens, in which there is no such arrangement of woody tissue, so called vasa propria, or spiral vessels.

Endogens have no bark. They have a cortical integument composed of an epiphlœum and an inner layer, analogous perhaps to liber; and the woody part of which, according to Mohl, is formed in Palms by the introduction of the ends of the woody arcs of the stem. In Tamus elephantipes the epiphlœum acquires the nature of cork, but splits into pyramidal laminated areæ. This approximates the cortical integument of Endogens very little to true bark, which is essentially characterized by being separable from the wood; and having its woody tissue parallel with that of the stem, and formed altogether in an independent, though parallel, direction.

SECT. III. *Of the Root, or Descending Axis.*

AT or about the same time that the ascending axis seeks the light and becomes a stem, does the opposite extremity of the seed or bud bury itself in the earth and become a root, with a tendency downwards so powerful, that no known force is sufficient to overcome it. Correctly speaking, nothing can be considered a root except what has such an origin; for those roots which are emitted by the stems of plants are in reality the roots of the buds above them, as will be hereafter explained. Nevertheless, nothing is more common than even for botanists to confound subterranean stems or buds with roots, as has been already seen. (See Bulb, Tuber, Soboles, &c. &c.)

Independently of its origin, the root is to be distinguished from the stem by many absolute characters. In the first place, its ramifications occur irregularly, and not with a symmetrical arrangement: they do not, like branches, proceed from certain fixed points (buds), but are produced from all and any points of the surface. Secondly, a root has no leaf-buds, unless indeed, as is sometimes the case, it has the power of forming adventitious ones; but, in such a case, the irregular manner in which they are produced is sufficient evidence of their nature. Thirdly, roots have no scales, leaves, or other appendages; neither do they ever indicate upon their surface, by means of scars, any trace of such: all underground bodies upon which scales have been found are stems, whatever they may have been called. A fourth distinction between roots and stems is, that the former have never any stomates upon their epidermis; and, finally, in Exogens the root has never any pith. It has been also said that roots are always colourless, while stems are always coloured; but aërial roots are often green, and all underground stems are colourless.

The body of the root is sometimes called the *caudex;* the minute subdivisions have been sometimes called *radicles,* — a term that should be confined to the root in the embryo;

others name them *fibrils*, — a term more generally adopted; while the terms *rhizina* and *rhizula* have been given by Link to the young roots of mosses and lichens.

A *fibril* is a little bundle of bothrenchyma, or sometimes of trachenchyma, encased in woody fibre, and covered by a lax cellular integument: it is in direct communication with the vascular system of the root, of which it is, in fact, only a subdivision; and its apex consists of extremely lax cellular tissue and mucus. This apex has the property of absorbing fluid with great force, and has been called by De Candolle the *Spongiole* or *Spongelet.* It must not be considered a particular organ; it is only the newly formed and forming tender tissue. In Pandanus the spongelets of the aërial roots consist of numerous very thin exfoliations of the epiphlœum, which form a sort of cup fit for holding water in.

The proportion borne by the root to the branches is extremely variable: in some plants it is nearly equal to them, in others, as in Lucerne, the roots are many times larger and longer than the stems; in all succulent plants and in Cucurbitaceæ they are much smaller. When the root is divided into a multitude of branches and fibres, it is called *fibrous:* if the fibres have occasionally dilatations at short intervals, they are called *nodulose.* When the main root perishes at the extremity, it receives the name of *præmorse*, or *bitten* off: frequently it consists of one fleshy elongated centre tapering to the extremity, when it is termed *fusiform* (or *tap-rooted* by the English, and *pivotante* by the French)*: if it is terminated by several distinct buds, as in some herbaceous plants, it is called *many-headed* (*multiceps*).

The roots of many plants are often fleshy, and composed of lobes, which appear to serve as reservoirs of nutriment to the

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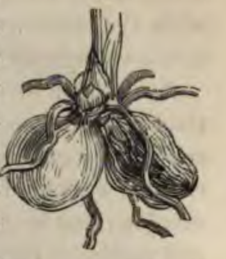
* In the former editions of this work the turnip has been referred to a root. But, from the investigations of Turpin and others, there is no room to doubt that the turnip, the radish, the cyclamen, and the elephant-foot, are all distensions of the stem: either of the first internodium, or of the inferior prolongation of the stem below the cotyledons and above the root.

46



fibrils that accompany them; as in many terrestrial Orchidaceous plants, Dahlias, &c. These must not be confounded either with tubers or bulbs, as they have been by some writers, but are rather to be considered a special form of the root, to which the name of *Tubercules* (*fig.* 46.) would not be inapplicable. In Orchis the tubercules are often palmated or lobed; in the Dahlia, and many Asphodeleæ, they hang in clusters, or are *fasciculated.*

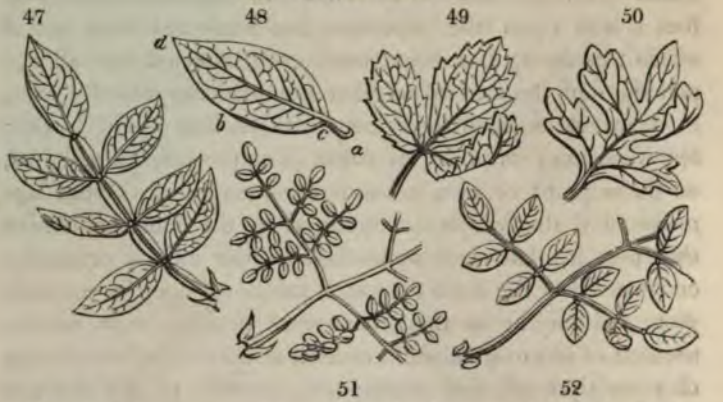
In internal structure the root differs little from the stem, except in being often extremely fleshy; its cellular system being subject to an unusually high degree of developement in a great many plants, as the Parsnip, and other edible roots. In Endogens, the mutual arrangement of the cellular and vascular systems of the root and stem is absolutely the same; but in Exogens, there is never any trace of pith in the root.

SECT. IV. *Of the Appendages of the Axis.*

FROM the outside of the stem, but connected immediately with its vascular system, arises a variety of thin flat expansions, arranged with great symmetry, and usually falling off after having existed for a few months. These are called, collectively, appendages of the axis; and, individually, scales, leaves, bracts, flowers, sexes, and fruit. They must not be confounded with mere expansions of the epidermis, such as ramenta, already described (p. 63.), from which they are known by having a connection with the vascular system of the axis. Till lately, botanists were accustomed to consider all these as essentially distinct organs; but, since the appearance of an admirable treatise by Goëthe in 1790, *On the Metamorphoses of Plants*, proofs of their being merely modifications of one common type, the leaf, have been gradually discovered; so that that which, forty years ago, was considered as the romance of a poet, is now universally acknowledged to be an indisputable truth. It may, however, be remarked, that when those who first seized upon the important but neglected facts out of which this theory has been constructed, asserted that all appendages of the axis of a plant are metamorphosed leaves, more was stated than the evidence at that time would justify; for we cannot say that an organ is a metamorphosed leaf, when, in point of fact, it has never been a leaf. What was meant, and that which is supported by the most conclusive evidence, is, that every appendage of the axis is originally constructed of the same elements, arranged upon a common plan, and varying in their manner of developement, not on account of any original difference in structure, but on account of especial, local, and predisposing causes: of this the leaf is taken as the type, because it is the organ which is most usually the result of the developement of those elements,— is that to which the other organs generally revert, when, from any accidental disturbing cause, they do not sustain the appearance to which they were originally predisposed, — and moreover, is that in which we have the most complete type of organisation.

It is not my intention just now to enter into separate discussion of this doctrine; proof of it will be more conveniently adduced as the different modifications of the appendages of the axis come respectively under consideration. The leaf, as the first that is formed, the most perfect of them all, and that which is most constantly present, is properly considered the type from which all the others are deviations, and is the part with the structure of which it is first necessary to become acquainted.

1. Of the Leaf.



The leaf is an expansion of the bark at the base of a leaf-bud, prior to which it is developed. In most plants it consists of cellular tissue, filling up the interstices of a net-work of fibres which proceed from the stem, and ultimately separating from the bark by an articulation; in many Monocotyledonous plants, Ferns and Mosses, no articulation exists, and the base of the leaf only separates from its parent stem by rotting away.

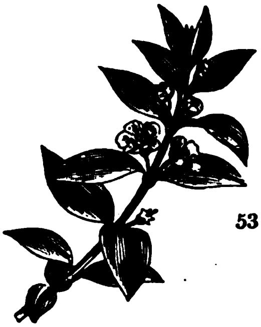
This difference of organisation has given rise to a distinction, on the part of Oken, between the articulated leaves of Dicotyledons and the inarticulated leaves of Monocotyledons and Acotyledons: the former he calls true leaves, and distinguishes by the name of *Laub;* the latter he considers foliaceous dilatations of the stem, analogous to leaves, and calls *Blatt.*

A leaf consists of two parts; namely, its stalk, which is called the *petiole* (*fig.* 48. *a*), and its expanded surface, which is called the *blade* or *lamina* (*fig.* 48. *c*, *b*, *d*): in ordinary language the latter term is not employed, but in very precise descriptions it is indispensable.

The point where the base of the upper side of a leaf joins the stem is called the *axil;* any thing which arises out of that point is said to be *axillary.* If a branch or other process proceeds from above the axil, it is called *supra-axillary;* if from below it, *infra-axillary.*

The scar formed by the separation of a leaf from its stem is sometimes called the *cicatricule.* The withered remains of leaves, which, not being articulated with the stem, cannot fall off, but decay upon it, have been called *reliquiæ* or *induviæ*, and the part so covered is said to be *induviate.*

When leaves are placed in pairs on opposite sides of a stem (*fig.* 53.), and on the same plane, they are called *opposite :* if more than two are opposite, they then form what is called a *whorl*, or *verticillus :* but if they arise at regular distances from each other round the stem, and not from the same plane, they are then called *alternate.*



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In plants having Exogenous stems, the first leaves, — namely, those which are present in the embryo itself (*cotyledons*), — are uniformly opposite; but those subsequently developed are either opposite verticillate, or alternate in different species: on the contrary, in Endogens, the embryo leaf is either solitary, or, if there are two, they are alternate; and those subsequently developed are usually alternate also, but few cases occurring in which they are opposite. Hence some have formed an opinion that the normal position of the leaves of Exogens is opposite, or verticillate; and that when the leaves are alternate, this arises from the extension of a node; while that of Endogens is alternate, the whorls being the result of the contraction of internodes.

But it seems more probable that the normal position of all leaves is alternate, and their position upon the stem an elongated spiral, as is in many cases exceedingly apparent, as, for instance, in the genus Pinus, in Pandanus, which is actually named Screw-pine, in consequence of the resemblance its shoots bear to a screw, and in the Pine-apple: the Apple, the Pear, the Willow, the Oak, will also be found to indicate the same arrangement, which is only less apparent because of the distance between the leaves, and the irregularity of their direction. If, in the Apple-tree for instance, a line be drawn from the base of one leaf to the base of another, and the leaves be then broken off, it will be found that a perfectly spiral line will have been formed. Upon this supposition, opposite or whorled leaves are to be considered the result of a peculiar non-developement of internodes, and the consequent confluence of as many nodes as there may be leaves in the whorl. Rhododendron ponticum will furnish the student with an illustration of this: on many of its branches some of the leaves are alternate and others opposite; and several intermediate states between these two will be perceivable. In many plants, the leaves of which are usually alternate, there is a manifest tendency to the approximation of the nodes, and consequently to an opposite arrangement of the leaves, as in Solanum nigrum, and many other Solanaceæ; while, on the other hand, leaves which are usually opposite, separate their nodes and become alternate, as in Erica mediterranea: but this is more rare.

The best argument in support of the hypothesis that all whorls arise from the non-developement of internodes and confluence of nodes, is, however, to be derived from flowers, which are several series of whorls, as will be seen hereafter. In plants with alternate leaves, the flowers often change into young branches, and then the whorls of which they consist are broken, the nodes separate, and those parts that were before opposite become alternate; and in monstrous Tulips, the whorls of which the flower consists are plainly seen to arise from the gradual approximation of leaves, which in their unchanged state are alternate.

A most elaborate memoir has been written by a German naturalist named Braun, to prove, mathematically, not only that the spiral arrangement is that which is everywhere visible in the disposition of the appendages of the axis, but that each species is subject to certain fixed laws, under which the nature of the spires, and in many cases their number, are determined. The original appeared in the *Nova Acta of the Imperial Academy Naturæ Curiosorum;* and a very full abstract of it has been given by Martins, in the first volume of the *Archives de Botanique*, from which I borrow what follows: —

The scales of the fruit of Coniferous plants are nothing but capellary leaves, which do not form, like the floral envelopes of other plants, a complete cavity surrounding the sexual organs on all sides, but which are slightly concave, and protect them on one side only. This point admitted, if we consider attentively the cone of a Pine, or of a Spruce Fir, we are at once led to inquire whether the scales are arranged in spires or in whorls. Breaking through its middle a cone of Pinus Picea (Silver Fir), we remark three scales, which at first sight appear to be upon the same plane; but a more attentive examination shows that they really originate at different heights, and moreover, that they are not placed at equal distances from each other; so that we cannot consider them a whorl, but only a portion of a very close spiral. But, considering the external surface of the cone viewed as a whole, we find that the scales are disposed in oblique lines, which may be studied —1. As to their *composition*, or the number of scales requisite to form one complete turn of the spire; 2d. As to their *inclination*, or the angle, more or less open, which they form with their axis; 3d. As to their total number, and their arrangement round the common axis, which constitutes their *co-ordination*. Finally, we may endeavour to ascertain whether the spires turn from right to left, or *vice versâ*.

He then proceeds to show, that the spiral arrangement is not only universal, but subject to laws of a very precise nature. The evidence upon which this is founded is long and ingenious, but would be unintelligible without the plates which illustrate it. I must, therefore, content myself with mentioning the results. Setting out from the Pine cone above referred to, he found that several series of spires are discoverable in the arrangement of their scales, and that there invariably exists between these spires certain arithmetical relations, which are the expression of the various combinations of a certain number of elements, disposed in a regular manner. All the spires depend upon the position of a fundamental series, from which the others are deviations. The nature of the fundamental series is expressed by a fraction, of which the numerator indicates the whole number of turns required to complete one spire, and the denominator the number of scales or parts that constitute it. Thus $\frac{8}{21}$ indicates that eight turns are made round the axis before any scale or part is exactly vertical to that which was first formed, and the number of scales or parts that intervene before this coincidence takes place is 21.

The following are some of the results thus obtained by Braun, in studying the composition of the spires of different plants:—

$\frac{1}{2}$ in Asarum, Aristolochia, Lime tree, Vetch, Pea, the spikes of all grasses.

$\frac{1}{3}$ is rare in Diotyledons, and generally changes into more complicated spires. It exists in Cactus speciosus, and some others.

$\frac{2}{5}$ is the most common of all, and represents the quincunx. Mezereum, Lapsana communis, Polemonium cœruleum, Potato, are examples.

$\frac{3}{8}$ is also common, as in the Bay-tree, the Holly, common Aconite, and the tuft of radical leaves of Plantago media.

$\frac{5}{13}$ exists where the leaves are numerous and their intervals small. Wormwood, common Arbutus, dwarf Convolvulus, and the tufts of leaves in London Pride and Dandelion, are instances.

$\frac{8}{21}$ in Woad, Plantago lanceolata, the bracts of Digitalis lanata.

$\frac{13}{34}$ in Sempervivum arboreum, the bracts of Plantago media, and of Protea argentea.

$\frac{21}{55}$ was found on an old trunk of Zamia horrida, and two species of Cactus (coronarius and difformis).

It does not, however, appear that this inquiry has led to any thing beyond the establishment of the fact, that, beginning from the cotyledons, the whole of the appendages of the axis of plants—leaves, calyx, corolla, stamens, and carpels—form an uninterrupted spire, governed by laws which are nearly constant. No application of the doctrine appears practicable, except to assist in the distinction of species, for which it would be well adapted, if the determination of the series with the requisite precision were less difficult; this is shown in the following instances of differences in the fundamental spire in nearly allied species.

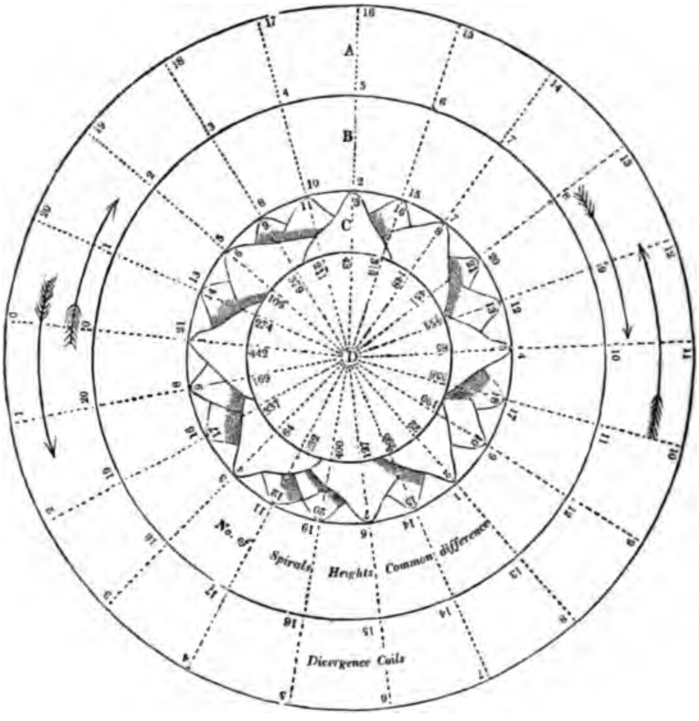
Pinus pinaster, $\frac{21}{55}$—sylvestris, $\frac{13}{34}$—cembra, $\frac{8}{21}$—larix, $\frac{8}{21}$—microcarpa $\frac{2}{5}$.

Betula alba and pubescens, $\frac{8}{21}$ and $\frac{13}{34}$—fruticosa generally, $\frac{5}{13}$.

Corylus avellana, $\frac{8}{21}$—americana and tubulosa, $\frac{13}{34}$ in their male catkins.

The whole of this curious question has been simplified by Professor Henslow, in observations printed for private circulation; and I am happy to be able, by the permission of their author, to lay them in this place before the public.

54



" The scales on a cone of the Spruce Fir (*Abies excelsa*) are placed spirally round the axis, at equal intervals; and after eight coils of the spiral, the twenty-second scale ranges vertically over the first. If this arrangement be referred to a cylinder, and then projected on a plane cutting its axis at right angles, the angular distance (*Divergence*) between two contiguous scales, seen from the centre, is $\frac{1}{21}$ of the circumference. Hence the divergence of the generating or primary spiral $\frac{8}{21}$. The various peculiarities of the secondary spirals which result from the above arrangement, may be seen by inspecting *fig.* 54.

A. If any figure in this circle represent the divergence of a spiral, the same will also represent the number of coils which that spiral must make before the twenty-second scale upon it comes vertically over the first.

B. The figures in this circle (corresponding to the several divergencies in A.) show the number of similar and parallel spirals which must be coiled round the cylinder, in order that *every* scale may range upon them.

The same figures also indicate the height of each spiral— viz.: either the *comparative* lengths of the vertical lines between scales 1. and 22. or the distance between two horizontal circles through scales 1. and 2.; and, lastly,

These figures are the *common differences* in the different arithmetic series apparent on the consecutive scales of each spiral.

C is the arrangement of the first twenty-one scales on the generating spiral.

D shows the number on the scales which begin a *second series* of each kind of spiral, *i. e.* the numbers on their twenty-second scales.

N. B. The number on the scale which begins a fresh series of *any* spiral is found by the formula (a + 21 B) where (a) = the number on the scale beginning a former series of the spiral, and B the common difference of the numbers on two contiguous scales.

Ex. Gr. Considering the spiral (*fig.* 55.) through the scales 1. 9. 17. &c., 153. 161. 169. &c. A. 1st, Its divergence (from 1 to 9) is 100—20, and, 2d, It must coil once towards the left, or twenty times towards the right (of a spectator at the axis) before it passes through the twenty-second scale upon it (viz. No. 169.), which ranges vertically over the first. B. 1st, There are seven other similar spirals parallel to it. 2d, Their height (as from 1 to 169) = eight times the height from 1 to 22; d, 3d, The common difference of the numbers of the scales

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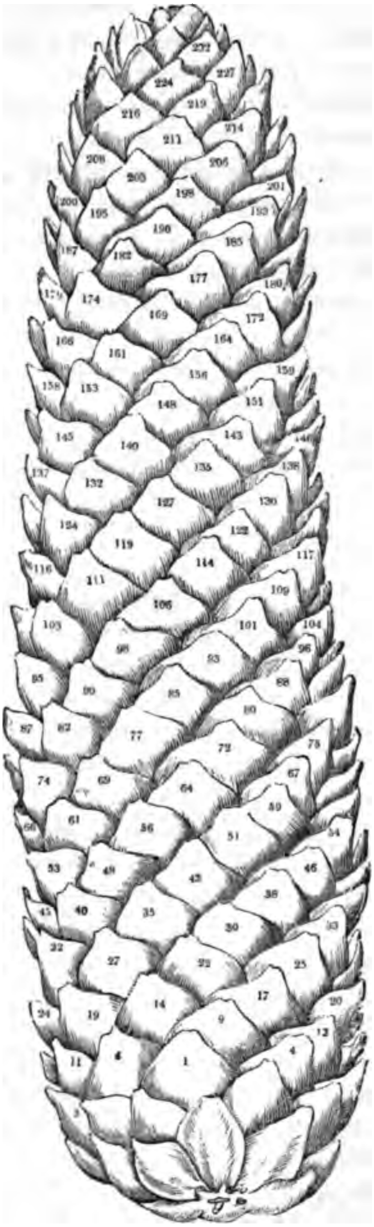
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is also eight. The position of the several *beginnings* of the 8 spirals (viz. on Nos. 1. to 8.) is shown in C; and in D we have the numbers (169. 106. 43. &c.) which respectively begin the second series of each spiral.

To discover the primary spiral, we may fix on any scale as a point of departure (No. 1.), and then, by numbering the scales on two of the secondary spirals (as 1. 9. 17. &c. and 1. 6. 11. &c.) which proceed in opposite directions, we may afterwards very readily place the numbers on all the scales. The easiest method of obtaining the common differences (viz. 8 and 5), for the purpose of numbering the scales in the two cases selected, is to draw a circle round the cone, and count the number of each of the two kinds of spirals intersecting it (which will be 8 of the first and 5 of the second). When a secondary spiral perfects a complete coil (as 1. 9. &c. 161. 169.), the number of the spirals of the same kind is readily seen; but the former mode for obtaining this number will apply equally well to cases where the cone is too short for the coils to be completed.

It is obvious that the hypothesis of the spiral arrangement of the foliaceous organs of plants is a mathematical question having but little relation to Botany. Those who wish to investigate it, will find all that is known of it in *Steinheil's* Observations upon the Theory of Phyllotaxis, in *Ann. Sc.* n. s. IV. 100. 142, *Bravais*, sur la disposition des feuilles curvisériées, ib. VII. 42. and VIII. 161., *Link*, Elementa Botanica, ed. 2: II. 448., *Dutrochet*, Mémoires, I. 238.

In their normal state leaves are obviously distinct, both from each other and from the stem. But, in some cases, adhesions of various kinds occur, and give them a new character. Thus, in Cardui, and many other thistle-like plants, the elongated bases of the leaves adhere to the stem, and become what is called *decurrent*. The elevated lines upon the stem, thus formed, are called by Link and Klotzsch *sterigmata: vera*, when traversed by a cord of vessels; *spuria*, when mere elevated cellular plates. In Bupleurum perfoliatum the lobes of the base of the leaf not only cohere with the stem, but projecting beyond it, grow together, so as to resemble a leaf through which the stem has pierced: this is called being *perfoliate*. Frequently two opposite leaves grow together at the base, as in Caprifolium perfoliatum; to this modification the latter term is often also applied, but that of *connate* is what more properly belongs to it.

The anatomical structure of the leaf is this: — From the medullary sheath diverges a bundle of woody tissue, accompanied by spiral vessels: this passes through the bark, and proceeds, at an angle more or less acute, to a determinate distance from the stem, branching off at intervals, and, by numerous ramifications, forming a kind of network. At the point of the stem whence the bundle of fibro-vascular tissue issues, the cellular tissue of the bark also diverges, accompanying the fibro-vascular tissue, expanding with its ramifications, and filling up their interstices. The tissue that proceeds from the medullary sheath, after having passed from the origin of the leaf to its extremity, doubles back upon itself, forming underneath the first a new layer of fibre, which, upon its return, converges just as the first layer diverged, at length combining into a single bundle, corresponding in bulk and position to that which first emerged, and finally discharging itself into the liber. If, therefore, a section of the leaf and stem be carefully made at a nodus, it will be found that the bundle of woody tissue which forms the frame-work of the leaf communicates above with the medullary sheath, and below with the liber. This is easily seen in the spring, when the leaves are young; but is not so visible in the autumn, when their existence is drawing to a close. The double layer of fibrovascular tissue is also perceptible in a leaf which has laid during the winter in some damp ditch, where its cellular substance has decayed, so that the cohesion between the upper and lower layers is destroyed, and the latter can be easily separated. The curious Indian leaves which have the property of opening, upon slight violence, like the leg of a silk stocking, so that the hand may be thrust between their upper and lower surfaces, derive that singular separability from an imperfect union between the layer of excurrent and recurrent fibre. De Candolle remarks, that, when the fibres expand to form the limb of a leaf, they may (whether this phenomenon occurs at the extremity of a petiole, or at the point of separation from the stem) do so after two different systems: they may either constantly preserve the same plane, when common flat leaves are formed; or they may expand in any direction, when cylindrical or swollen or triangular leaves are the result. (*Organogr.* p. 270.)

The cellular tissue of which the rest of the leaf is composed is parenchyma, which Link then calls *diachyma*, or that immediately beneath the two surfaces *cortex*, and the intermediate substance *diploe*. De Candolle calls these two, taken together, the *mesophyllum*. The whole is protected, in leaves exposed to air, by a homogeneous cuticle of indurated organic mucus (p. 1.), and a coating of epidermis, furnished with stomates; but in submersed leaves the parenchyma is naked, no epidermis overlying it.

The general nature of the parenchymatous part of leaves has been explained, both by Link and others, and figured by Mohl, firstly in 1828 (*Uber die Poren des Pflanzenzellgewebes*, tab. i. fig. 4, &c.), and afterwards in his elaborate enquiry into the anatomy of Palms. A very complete account is that of Adolphe Brongniart, in 1830 (*Annales des Sc.* vol. xxi. p. 420.), of which much of what follows is an abstract.

The epidermis is a layer of vesicles adhering firmly to each other, and sometimes but slightly to the subjacent tissue, from which they are entirely different in form and nature: in form, for their cellules are depressed, and, in consequence of the variety of outline that they present, arranged in meshes either regular or irregular; and in nature, because these bladders are perfectly transparent, colourless, and probably filled with either air or rarefied fluid, — for the manner in which light passes through them proves that they do not contain dense fluid. They scarcely ever contain any organic particles, and are probably but little permeable either to fluids or gaseous matters; while, on the other hand, the vesicles of the subjacent parenchyma are filled with the green substance which determines the colour of the leaf. The epidermis is not always formed of a single layer of vesicles, but in some cases consists of two, or even three. No trace is discoverable of vessels either terminating in or beneath the cuticle; Brongniart states this most explicitly, and my own observations are in accordance with his: an opinion, therefore, which some botanists have entertained, that spiral vessels terminate in the stomates (D. C. *Organogr.* p. 272. &c.), must be abandoned. At the margin of a leaf the epidermis is generally harder than elsewhere, and sometimes becomes so indurated as to assume a flinty texture, as in the Aloe, and many other plants.

Stomates are found upon various parts of the epidermis: in some plants only on that of the under side of leaves, in others on the upper also; in floating leaves upon the latter only. When leaves are so turned that their margins are directed towards the earth and the heavens, the two faces are then alike in appearance, and are both equally furnished with stomates. In succulent leaves they are said to be either altogether absent or very rare; but this is not exactly the fact. They are fewer and smaller, and perhaps more imperfect, in succulent than in other parts, but by no means absent. According to the observations of De Candolle (*Organogr.* p. 272.), they are, in the Orange and Mesembryanthemum, as ten in the former to one in the latter.

I have remarked (*Bot. Reg.* 1540.) the singular fact, that certain plants have the power of forming stomates on the upper surface of their leaves, if from any cause their leaves are inverted. Thus the stomates are usually upon the under side of leaves, where also the veins are more prominent, and hairs appear exclusively, if hairs are found upon only one of the two surfaces. In Alströmeria that side of the leaves which is organically the undermost becomes, in consequence of a twist in the petiole, the uppermost, and that side which is borne uppermost is turned undermost; and then the organic underside, being turned uppermost, has no stomates; while the organic upper side, being turned downwards, although under other circumstances it would have neither stomates, hairs, nor elevated veins, acquires all those characters in consequence of its inversion. A very curious observation, in connection with this subject, has been made by Mirbel, in his memoir upon the structure of Marchantia polymorpha.

The young bulbs by which this plant is multiplied are originally so homogeneous in structure, that there is no apparent character in their organisation to show which of their faces is destined to become the upper surface, and which the under. For the purpose of ascertaining whether there existed any natural but invisible predisposition in the two faces to undergo the changes which subsequently become so apparent, and by means of which their respective functions are performed, or whether the tendency is given by some cause posterior to their first creation, the following experiments were instituted: — Five bulbs were sown upon powdered sandstone, and it was found that the face which touched the sandstone produced roots, and the opposite face formed stomates. It was, however, possible that the five bulbs might have all accidentally fallen upon the face which was predisposed to emit roots; other experiments of the same kind were therefore tried, first with eighty, and afterwards with hundreds of little bulbs, — and the result was the same as with the five. This proved that either face was originally adapted for producing either roots or stomates, and that the tendency was determined merely by the position in which the surfaces were placed. The next point to ascertain was, whether the tendency once given could be afterwards altered. Some little bulbs, that had been growing for twenty-four hours only, had emitted roots; they were turned, so that the upper surface touched the soil, and the under was exposed to light. In twenty-four hours more the two faces had both produced roots: that which had originally been the under surface went on pushing out new roots; that which had originally been the upper surface had also produced roots: but in a few days the sides of the young plants began to rise from the soil, became erect, turned over, and finally recovered in this way their original position, and the face which had originally been the uppermost immediately became covered with stomates. It, therefore, appears that, the impulse once given, the predisposition to assume particular appearances or functions is absolutely fixed, and will not change in the ordinary course of nature. This is a fact of high interest for those who are occupied with researches into the causes of what is called vegetable metamorphosis.

The parenchyma is, if casually examined, or even if viewed in slices of too great thickness, apparently composed of heaps of small green bladders, arranged with little order or regularity; but if very thin slices are taken and viewed with a high magnifying power, it will be seen that nothing can be more perfect than the plan upon which the whole structure is contrived, and that, instead of disorder, the most wise order pervades the whole. Upon this subject I extract the words of Adolphe Brongniart: — "There exists beneath the upper cuticle two or three layers of oblong blunt vesicles, placed perpendicular to the surface of the leaf, and generally much less in diameter than the bladders of the cuticle; so that they are easily seen through it. These vesicles, which appear specially destined to give solidity to the parenchyma of the leaf, have no other intervals than the little spaces that result from the contact of this sort of cylinder: nevertheless, in plants that have stomates on the upper surface of their leaves, as is the case in most herbaceous plants, and in such as float on the surface of water, there exists here and there among the vesicles some large spaces, through which the stomates communicate with the interior of the leaf.

"This parenchyma is entirely different from what is found beneath the cuticle of the lower side. There, instead of consisting of regular cylindrical vesicles, it is composed of irregular ones, often having two or three branches, which unite with the limbs of the vesicles next them, and so form a reticulated parenchyma; the spaces between whose vesicles are much larger than the vesicles themselves.

"It is this reticulated tissue, with large spaces in it (to which the name of cavernous or spongy parenchyma might not improperly be applied), that, in most cases, occupies at least half the thickness of the leaves between the veins. The arrangement of the vesicles is very obvious if the lower cuticle of certain leaves be lifted up with the layer of parenchyma that is applied against it; it may then be seen that these anastomosing vesicles form a net with large meshes — a sort of grating — inside the cuticle. It must not, however, be supposed that this structure, which I have remarked in several ferns, and in a great many dicotyledonous plants, is without exception. In many monocotyledonous and succulent plants we have some remarkable modifications of this structure. Thus, in the Lily, and several plants of the same family, the vesicles of parenchyma that are in contact with the lower cuticle are lengthened out, sinuous, and toothed, as it were, at the sides: these projections join those of the contiguous vesicle; and a number of cavities is the consequence, which render this sort of parenchyma permeable to air. An analogous arrangement exists in the lower parenchyma of Galega. In the Iris, there is scarcely any space between the oblong and polyhedral vesicles which form the parenchyma; but it is remarked, that the subjacent parenchyma is wanting at every point where the cuticle is pierced by a stomate. In such succulent plants as I have examined, the spaces between the cellules of parenchyma are very small; but, nevertheless, here and there, there are often larger cavities, which either correspond directly with the stomates, or are in communication with them. The same thing happens in plants with floating leaves, where the stomates placed on the upper surface correspond with the layer of the cylindrical and parallel vesicles; in such case there are, here and there, between these vesicles, empty spaces which almost always correspond to the points where the stomates exist, and which permit the air to penetrate between the vesicles as far as the middle of the parenchyma of the leaf."

Thus much Adolphe Brongniart; who adds, that in submersed leaves there is no cuticle, but the whole consists of solid parenchyma alone, in which there are no other cavities than such as are necessary to float the leaves. The observations of Mohl, Meyen, and myself generally confirm this; but, at the same time, numerous cases exist in which the texture of the leaf has been found to be nearly the same throughout; in fact, the only circumstance which is found to be uniform in respect to the internal anatomy of leaves is, that their parenchyma is cavernous, and that the air cavities are uniformly in communication with the stomates.

Dutrochet states in addition (*Ann. des Sc.*, xxv. 245.) that the interior of a leaf is divided completely by a number of partitions covered by the ribs and principal veins, so that the air cavities have not actually a free communication in every direction through the parenchyma; but are, to a certain extent, cut off from each other. This is conformable to what

Mirbel has described in Marchantia, where the leafy expansions are separated by partitions into chambers, between which, he is of opinion, there is no other communication than what results from the permeability of the tissue.

The veins being elongations of the medullary sheath, necessarily consist of woody tissue and vessels, to which is added cinenchymatous tissue. In submersed leaves spiral vessels are often wanting, the veins consisting of nothing but woody tissue.

Such are the general anatomical characters of leaves; but it must be borne in mind, that, in different species, they undergo a variety of remarkable modifications. These arise either from the addition of parenchyma, when leaves become *succulent*, or from the non-developement of it when they become *membranous*, or from the total suppression of it, and even of the veins also in great part, as in those which are called *ramentaceous*, such as the primordial leaves of the genus Pinus. Occasionally, the veins only are formed, the parenchyma being deficient, as in Ranunculus aquatilis, the very curious Hydrogeton or Ouvirandra, and various species of Podostemaceæ.

It has already been seen that a leaf may consist of two distinct parts; the *petiole*, or stalk, and the *lamina*, or blade: both of these demand separate consideration. These are, however, not necessarily present; the petiole may exist without the lamina, as in *leafless* Acacias, or the lamina without the petiole, in all *sessile* leaves.

The BLADE *lamina* (or *limbus*, as it is called by some) is subject to many diversities of figure and division; most commonly it forms an approach to oval, being longer than broad. It is described by two opposite arcs, whose points of intersection are the apex and base.

That extremity of the blade which is next the stem is called its *base;* the opposite extremity, its *apex;* and the line representing its two edges, the *margin* or *circumscription*.

If the blade consists of one piece only, the leaf is said to be *simple*, whatever may be the depth of its divisions: thus, the entire blade of the Box tree, the serrated blade of the Apple leaf, the toothed blade of Coltsfoot, the runcinate blade of Taraxacum, the pinnatifid blade of Hawthorn (which is often divided almost to its very midrib), are all considered to belong to the class of simple leaves. But if the petiole branches out, separating the cellular tissue into more than one distinct portion, each forming a perfect blade by itself, such a leaf is often said to be *compound*, whether the divisions be two, as in the conjugate leaf of Zygophyllum, or indefinite in number, as in the many varieties of pinnated leaves. Another notion of a compound leaf consists in its divisions being articulated with the petiole, by which it is better distinguished from the simple leaf than by the number of its divisions. Thus, the pinnated leaf of a Zamia, and the pedate leaf of an Arum, both in this sense belong to the class of simple leaves; while the solitary blade of the Orange, the common Barberry, &c. are referable to the class of compound leaves. This distinction is said to be of some importance to the student of natural affinities; for, while division of whatever degree may be expected to occur in different species of the same genus or order (provided there is no articulation), it rarely happens that such compound leaves, as are articulated with their petiole, are found in the same natural assemblage with those in which no articulation exists. Alphonse De Candolle remarks, however, that in Gleditschia, whose leaves are mostly articulated, we find some leaves with their leaflets united, and therefore not articulated with their midrib; and this, and other similar instances, diminishes the value of articulation as the test of a compound leaf; moreover, in such apparently simple leaves as those of Zamia, the leaflets are, in fact, articulated with their midrib, as is proved by macerating them, when they spontaneously disarticulate.

In speaking of the *surface* of a leaf it is customary to make use of the word *pagina*. Thus, the upper surface is called *pagina superior*; the lower surface, *pagina inferior*. The upper surface is more shining and compact than the under, and less generally clothed with hairs; its veins are sunken; while those of the lower surface are usually prominent. The epidermis readily separates from the lower surface, but with difficulty from the upper. There are frequently hairs upon the under surface while the upper is perfectly smooth; but there are few instances of the upper surface being hairy while the lower is smooth.

The ramifications of the petiole among the cellular tissue of the leaf are called *veins*, and the manner of their distribution is termed *venation*. This influences in a great degree the figure and general appearance of the foliage. The vein which forms a continuation of the petiole and the axis of the leaf is called the midrib or *costa:* from this all the rest diverge, either from its sides or base. If other veins similar to the midrib pass from the base to the apex of a leaf, such veins have been named *nerves;* and a leaf with such an arrangement of its veins has been called a *nerved* leaf. In speaking of these parts, a leaf is said to be *three*, or *five*, or otherwise *nerved*, if the so-called nerves all proceed from the very base of the lamina, but it is called *triple*, *quintuple*, &c. *nerved*, if the nerves all proceed from above the base of the lamina. If the veins diverge from the midrib towards the margin, ramifying as they proceed, such a leaf has been called a *venous* or *reticulated* leaf. This is the sense in which these terms were used by Linnæus; but Link and some others depart from so strict an application of them, calling all the veins of a plant nerves, whatever may be their origin or direction.

The veins are, however, improperly called nerves, either in all cases, as by Link, or in certain cases only, when they have a particular size or direction, as by Linnæus and his followers. Nothing is more destructive of accurate ideas in natural history than giving names well understood in one kingdom of nature to organs in another kingdom of a different kind, unless it is the, perhaps, more reprehensible practice of giving two names conveying different ideas to the same organ in the same kingdom of nature. Thus, when the veins of a plant are termed nerves, it is naturally understood that they exercise functions of a similar nature to those of the nerves of animals: if otherwise, why are they so called? But they exercise no such functions, being mere channels for the transmission of fluid. Again, if one portion of the skeleton of a leaf is called a vein, and another portion a nerve, this apparently precise mode of speaking leads yet more strongly to the belief that the structure and function of those two parts are as widely different as the structure and function of a vein and a nerve in the animal economy; else why should such caution be taken to distinguish them? But, in fact, there is no difference whatever, except in size, between the veins and nerves of a leaf.

For the sake of obtaining great precision in describing such a very important and various-formed organ as the leaf, many terms have been invented, especially by Link and De Candolle, which, although not used in daily parlance, are important where brevity and precision are required. Without exactly adopting the nomenclature of either of these distinguished writers, it appears that upon it a system of names may be founded, to which the systematist can have little to object.

It has been usual to call that bundle of vessels only which passes directly from the base to the apex of a leaf the *rib*, or *costa*, or midrib. This term should be extended to all main veins proceeding directly from the base to the apex, or to the points of the lobes. There is no difference in size in these ribs; and in lobed leaves, which may be understood as simple leaves approaching composition, each rib has its own particular set of veins.

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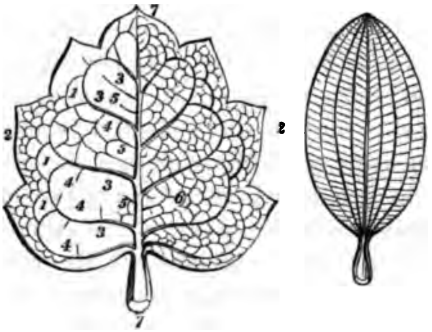


The midrib (*fig.* 56. 7) sends forth alternately, right and left along its whole length, ramifications of less dimensions than itself, but more nearly approaching it than any other veins: these may be called *primary veins* (*fig.* 56. 3). They diverge from the midrib at various angles, and pass to the margin of the leaf, curving towards the apex in their course, and finally, at some distance within the margin, forming an anastomosis with the back of the primary vein, which lies next them. That part of the primary vein which is between the anastomosis thus described, having a curved direction, may be called the *curved vein*. Between this latter and the margin, other veins, proceeding from the curved veins, with the same curved direction, and of the same magnitude, occasionally intervene: they may be distinguished by the name of *external veins* (*fig.* 56. 1). The margin itself and these last are connected by a fine net-work of minute veins, which I would distinguish by the name of *marginal veinlets*. From the midrib are generally produced, at right angles with it, and alternate with the primary veins, smaller veins; which may not improperly be named *costal veins* (*fig.* 56. 5). The primary veins are themselves connected by fine veins, which anastomose in the area between them; these veins, when they immediately leave the primary veins, I would call *proper veinlets* (*venulæ propriæ*) (*fig.* 56. 4); and where they anastomose, *common veinlets* (*ven. communes*). The area of parenchyma, lying between two or more veins or veinlets, I name with the old botanists *intervenium*.

These distinctions may to some appear over-refined; but I am convinced that no one can very precisely describe a leaf without the use either of them, or of equivalent terms yet to be invented. With respect to their venation only, leaves may be conveniently arranged under the following heads:—

1. *Veinless* (*avenium*), when no veins at all are formed, except a slight approach to a midrib, as in Mosses, Fuci, &c. Leaves of this description exist only in the lowest tribes of foliaceous plants, and must not be confounded with the fleshy or thickened leaves common among the higher orders of vegetation, in which the veins are by no means absent, but only concealed within the substance of the parenchyma. (See No. 10.) Of this De Candolle has two forms,—first, his *folia nullinervia*, in which there is not even a trace of a midrib, as in *Ulva ;* and second, his *folia falsinervia*, in which a trace of a midrib is perceptible. These terms appear to me un-

necessary; but, if they be employed, the termination *nervia* must be changed to *venia*.

2. *Equal-veined* (*æqualivenium*), when the midrib is perfectly formed, and the veins are all of equal size, as in Ferns. This kind of leaf has not been before distinguished: it may be considered intermediate between those without veins and those in which primary veins are first apparent. The veins are equal in power to the proper veinlets of leaves of a higher class.

3. *Straight-veined* (*rectivenium*). In this the veins are entirely primary, generally very much attenuated, and arising from towards the base of the midrib, with which they lie nearly parallel: they are connected by proper veinlets; but there are no common veinlets. The leaves of Grasses and of Palms and Orchidaceous plants are of this nature. This form has been called by Link *paralleli-* and *convergenti-nervosum*, according to the degree of parallelism of the primary veins; and to these two he has added what he calls *venuloso-nervosum*, when the primary veins are connected by proper veinlets: but as this is always so, although it is not in all cases equally apparent, the term is superfluous. Ach. Richard calls this form *laterinervium*, and De Candolle *rectinervium*; from which I do not find it advisable to distinguish his *ruptinervium*, which indicates the straight-veined leaf, when the veins are thickened and indurated, as in the Palm tribe.

4. *Curve-veined* (*curvivenium*). This is a particular modification of the last form, in which the primary veins are also parallel, simple, and connected by unbranched proper veinlets; do not pass from near the base to the apex of the leaf, but diverge from the midrib along its whole length, and lose themselves in the margin. This is the *folium hinoideum* and *venuloso-hinoideum* of Link, the *f. penninervium* of A. Richard, and the *f. curvinervium* of De Candolle. It is common in Zingiberaceæ. It is supposed by the last named Botanist that both this and the last ought to be regarded as peculiar modifications of petiole (a kind of phyllodia), rather than as true leaves analogous to those next to be described.

5. *Netted* (*reticulatum*). Here the whole of the veins which constitute a completely developed leaf are present, arranged

as I have above described them, there being no peculiar combination of any class of veins. This is the common form of the leaves of Dicotyledons, as of the Lilac, the Rose, &c. It is the *folium venosum* of Linnæus, the *f. indirectè venosum* of Link, the *f. mixtinervium* of A. Richard, and the *f. retinervium* of De Candolle. If the external veins and marginal veinlets are conspicuous, Link calls this form *combinatè venosum;* but if they are indistinct, he calls it *evanescentè venosum.*

6. *Ribbed* (*costatum*). In this three or more midribs proceed from the base to the apex of the leaf, and are connected by branching primary veins of the form and magnitude of proper veinlets, as in Melastoma. This must not be confounded with the *straight-veined* leaf, from which it may in all cases of doubt be distinguished by the ramified veins that connect the ribs. This is a very material difference, which has never been properly explained. Linnæus and his followers confound the two forms; but modern writers separate them: although it must be confessed that it is difficult to discover their distinctions from the characters hitherto assigned to them. Link calls these leaves *f. nervata,* A. Richard *f. basinervia,* and De Candolle *f. triplinervia* and *f. quintuplinervia.* If a ribbed leaf has three ribs springing from the base, it is said to be *three-ribbed* (*tri-costatum, trinerve* of authors); if five, *five-ribbed,* and so on. But if the ribs do not proceed exactly from the base, but from a little above it, the leaf is then said to be *triple-ribbed* (*triplicostatum*), as in the Helianthus.

7. *Falsely ribbed* (*pseudocostatum*), is when the curved and external veins, both or either, in a reticulated leaf, become confluent into a line parallel with the margin, as in all Myrtaceæ. This has not been before distinguished.

8. *Radiating* (*radiatum*), when several ribs radiate from the base of a reticulated leaf to its circumference, as in lobed leaves. This and the following form the *f. directè venosum* of Link: it is the *f. digitinervium* of A. Richard. Hither I refer, without distinguishing them, the *f. pedalinervia, palminervia,* and *peltinervia* of De Candolle; the differences of which do not arise out of any peculiarity in the venation, but from the particular form of the leaves themselves.

9. *Feather-veined* (*pennivenium*), when the venæ primariæ of a reticulated leaf pass in a right line from the midrib to the margin, as in Castanea. This has the same relation to the radiating leaf that the curve-veined bears to the straight-veined; it is the *folium penninervium* of De Candolle.

10. *Hidden-veined* (*introvenium*). To this I refer all leaves the veins of which are hidden from view by the parenchyma being in excess, as in *Hoya*, and many other plants. Such a leaf is often inaccurately called veinless. De Candolle calls a leaf of this nature, in which the veins are dispersed through a large mass of parenchyma, as in Mesembryanthemum, *vaginervium*.

In case it should be necessary to explain the direction that the primary veins take when they diverge from the midrib, this can be denoted by measuring the angle which is formed by the midrib and the diverging vein, and can either be stated in distinct words, or by applying the following terms: — thus, if the angle formed by the divergence is between 10° and 20°, the vein may be said to be *nearly parallel* (*subparallela*); if between 20° and 40°, *diverging;* between 40° and 60°, *spreading;* between 60° and 80°, *divaricating;* between 80° and 90°, *right-angled;* between 90° and 120°, *oblique;* beyond 120°, *reflexed* (*retroflexa*).

With regard to the *forms of leaves*, this subject properly enters into Glossology; because the terms applied by Botanists to differences in the outline of those organs are, in fact, applicable to any varieties in the figure of any other flat body. Nevertheless, as it may be a matter of convenience to the student to know upon what principles the most remarkable forms of leaves, or of other divided parts, are thought to be connected with each other, I here translate the observations upon the subject made by Alphonse de Candolle, whose *Introduction to Botany* may be supposed to embody the latest opinions of his father.

"Leaves put on a multitude of forms, depending upon the manner in which they are severally organised, especially with regard to their division and the direction of their veins. These veins being in general symmetrical on the two sides of the midrib, leaves themselves are almost always of some regular figure, as, for instance, oval, rounded, elliptical, &c. Their regularity, however, is never mathematical; and there are certain leaves, like those of the Begonia, the two sides of which are most remarkably unequal.

" Leaves are either *entire*, that is, without toothings of any kind; or *toothed* in various ways upon their edges; or divided more or less deeply into *lobes*, which leave void spaces between them, which we call *recesses* (*sinus*).

" Differences of this kind only become intelligible when one starts from the idea that a leaf is a mere expansion of tissue, in which the parenchyma is more or less extended, according to the divergence of the vessels that compose the veins, and to the degree of vegetating vigour of every species upon all points of its surface. In this expansion, which constitutes vegetation, it may be understood that a cellular tissue, mingled with firm parts like veins, ought to assume, especially at the edges, very different appearances. Each vein is to be considered as surrounded with parenchyma as well as the ligneous fibres of the stem. When this parenchyma stretches a great deal between the principal veins, and unites them completely up to their extremities, the leaf is *entire;* but when the separation of the principal veins is greater, and the cellular tissue is comparatively less extended, the union of parenchyma takes place in only an imperfect manner, and thus lobes and openings are produced in the middle of the leaf, or various kinds of toothings in its circumference.

" In support of this theory, which has originated with M. De Candolle, it must be remarked that the bladders of cellular tissue have a great tendency to grow together when they come in contact in a young state. The fluids which tissue secretes are more or less viscid; the growth of the bladders in diameter causes them to press against each other; they are extremely homogeneous in different parts of the same organ; all these may be supposed to concur in producing the phenomenon of which the *grafting* of one plant upon another is the most striking example. The structure of flowers depends upon the existence of this tendency, as will be shown hereafter. With regard to leaves, Dracontium pertusum affords a verification of this theory in the irregular holes pierced through the middle of its blade between the veins. The more weak the developement of this leaf has been, the larger are the holes, which, in some instances, even extend to the margin, when the leaf beomes lobed. In this case it is difficult to deny that the parenchyma developes and combines more towards the edge of the leaf than in the centre; while, on the other hand, by a different direction and another mode of developement of the parenchyma, the contrary takes place in the greater part of leaves. The fact, that divisions are the deepest in those individuals of the same species whose vegetation has been least favoured by humidity and the nature of the soil, is a confirmation of this theory.

" Palm trees seemed to offer an exception to this mode of accounting for the formation of lobes; but the recent observations of Mohl have demonstrated that those plants also are conformable to the theory. The leaves of Palm trees begin by being apparently simple, they then gradually divide from the extremity to the base of the blade, and there are on the edges of the divisions some ragged remnants, which look as if they indicated an actual rending asunder. But Mohl, by observing these leaves microscopically, when first developing, ascertained that these divisions never are intimately united at their edges, and that they are merely held together by a net of down. This may possibly depend upon the dry and leathery texture of their leaves, which causes the bladders to be converted into hairs instead of uniting in consequence of their great approximation. If the adhesion is incomplete, it is no wonder that the leaves should separate in proportion as the veins diverge by the enlargement of the leaf. Palm leaves, then, are not, as has been supposed, simple leaves which divide into lobes contrary to what happens in other plants; they are divisions bordered by a parenchyma which has never been united to that of the division next it, and which, in consequence, does not tear, but only separates.

" The unequal degrees of union of the parenchyma that surrounds the veins, combined with the arrangement of the latter, form the principles on which the nomenclature of divided leaves has been contrived.

" When the parenchyma between the primary veins is not united, so that the blade is composed of several distinct parts combined by the midrib only, the distinct portions or lobes are called *segments.* They differ from the leaflets of more compound leaves merely by the circumstance of not being jointed with their support, nor deciduous. A leaf having such segments is called *dissected.*

"If the lobes are united near the base around the origin of these veins, we name them *partitions,* and the leaf is said to be *parted.*

"Supposing the lobes to be united as far as the middle, they become *divisions,* their recesses are *fissures,* and the adjectives formed from these are made to ènd in *fid,* as *multifid, quinquefid,* &c.; this should not be applied to any cases in which the divisions extend below the middle of the veins; it is, however, frequently applied to cases of a division as deep as the midrib.

"Finally, if the adhesion of the lobes is complete, and if the parenchyma which separates the extremity only of the veins is not extended to the extremity of the principal veins, or beyond them, the leaf is merely toothed (*dentate*); the salient parts are *toothings.* When the *toothings,* or *teeth,* are rounded, they become *crenels,* and the leaf is *crenelled* (or *crenate*). This form of leaf is not very important, because it is not connected with the arrangement of the primary veins, while that of the lobes, already mentioned, always is.

"The terms that express precisely the important subdivisions of the leaf are combined with those which indicate venation. Thus a feather-veined leaf (*pennivenium*) may be either *pennatisected,* or *pennatiparted,* or *pennatifid,* according as it has segments, partitions, or fissures. In like manner a *palm-veined* leaf (this is what I call radiating, p. 133.) may be *palmatisected, palmatiparted,* or *palmatifid;* and so on.

"In like manner we say that a leaf is *trisected, trifid,* or *triparted,* when we would draw attention to the number and depth of the lobes of a leaf, rather than to the relation they bear to the veins. And, on the other hand, we may, by neglecting the number of the lobes, simply indicate their presence by saying that a leaf is *pennatilobed, palmatilobed,* and so on.

"The lobes themselves are sometimes subdivided upon the same principle as the leaf itself. We then say that a leaf is *bipennatisected, bipennatiparted,* &c.; if the subdivisions of the lobes are themselves lobed, we may say *tripennatisected, tripennatiparted,* &c. Finally, in cases where leaves are extremely divided, and the parenchyma of the ultimate ramifications of the veins does not unite and form lobes, we say, in general terms, that the leaf is *multifid, laciniated, decomposed,* or *slashed;* terms which express the appearance of a leaf, without any very precise signification."

With regard to compound leaves, their leaflets always have the primary veins running at an angle more or less acute towards the margin. "This is perfectly intelligible if we reflect that their lateral veins represent not the primary, but the secondary and tertiary veins of simple leaves, which latter are always pennated.

"The leaflets of pennated leaves are usually placed opposite each other in pairs along a common petiole. Thèse pairs of leaves are called in Latin *juga:* thus a leaf with one pair is *unijugum;* with two pairs, *bijugum,* &c.

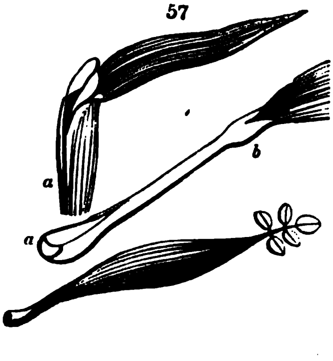
"Usually one of the leaflets terminates the petiole; the leaf is then *unequally pinnated* (*imparipinnatum*); but sometimes there is no odd leaflet, and the petiole ends abruptly, or in a point or tendril: this is *equally pinnated, pari-pinnatum.*

"Sometimes the leaflets themselves are subdivided into other leaflets (*folium bipinnatum, tripinnatum*). In this case, the lateral petioles which bear the leaflets are called *partial;* and the small supports of the leaflets themselves, *stalklets* (*petiolules*)."

Such are De Candolle's ideas of the typical formation of leaves. They offer a convenient mode of studying the modifications in structure of these organs, and are, to all appearance, founded upon a correct view of the subject.

The PETIOLE, or leafstalk (*fig.* 57., *a* — *b*), is what connects the blade with the stem, of which it was considered by Linnæus as a part. It consists of one or more bundles of fibro-vascular tissue surrounded by cellular substance.

57



Its figure is generally half cylindrical, frequently channelled on the surface presented to the heavens; but in some monocotyledonous plants it is perfectly cylindrical, and in others it is a thin leafy expansion, called the *sheath*, or *vagina*, surrounding the stem (*fig.* 57. *a*). If the petiole is entirely absent, which is often the case, the leaf is then said to be *sessile*. Generally the petiole is simple, and continuous with the axis of the leaf; sometimes it is divided into several parts, each bearing a separate leaf or *leaflet* (*foliolum*): in such cases it is said to be compound; each of the stalks of the leaflets being called *petiolules* or *stalklets* (*ramastra*, Jungius). In some leaves the petiole is continuous with the axis of the lamina, from which it never separates; in others the petiole is articulated with each stalklet; so that, when the leaf perishes, it separates into as many portions as there are leaflets, as in the Sensitive Plant. When an apparently simple leaf is found to be articulated with its petiole, as in the Orange, such a leaf is not to be considered simple, but as the terminal leaflet of a pinnated leaf, of which the lateral leaflets are not developed. This is an important difference, and must be borne constantly in mind by those engaged in the investigation of natural affinities.

At the base of the petiole, where it joins the stem, and upon its lower surface, the cellular tissue increases in quantity, and produces a protuberance or gibbosity, which Ruellius, and after him Link, called the *pulvinus*, and De Candolle *coussinet* (*fig.* 57. *a*). At the opposite extremity of the petiole, where it is connected with the lamina, a similar swelling is often remarkable, as in *Sterculia*, *Mimosa sensitiva*, and others: this is called the *struma*, or, by the French, *bourrelet*, (*fig.* 57. *b*).

Occasionally the petiole embraces the branch from which it springs, and in such case is said to be *sheathing;* and is even called a *sheath*, or *vagina*, as in grasses (*fig.* 57. *a*). When the lower part only of the petiole is sheathing, as in Apiaceæ, that part is sometimes called the *pericladium*. In grasses there is a peculiar membranous process at the top of the sheath, between it and the blade, which has received the name of *ligula* (*fig.* 57. *b*); for the nature of this process see page 145. In the Asparagus, the petiole has the form of a small sheath, is destitute of blade, and surrounds the base of certain small branches having the appearance of leaves; such a petiole has been named *hypophyllium* by Link. In Trapa natans, Pontedera crassipes, and other plants, the petiole is excessively dilated by air, and acts as a bladder to float the leaves; except being thus in a state of dilatation, it does not differ from common petioles: it has, nevertheless, received the name of *vesicula* from De Candolle, who considers it the same as the bladdery expansions of Fuci. The petiole is generally straight: occasionally it becomes rigid and twisted, so that the plant can climb by it. In Combretum it hardens, curves backwards, loses its blade, and by degrees becomes an exceedingly hard, durable hook, by means of which that plant is able to raise itself upon the branches of the trees in its vicinity.

When the petiole grows *upon* the angles of the stem it is called by Link *p. synedrus;* when between them, *p. cathedrus.*

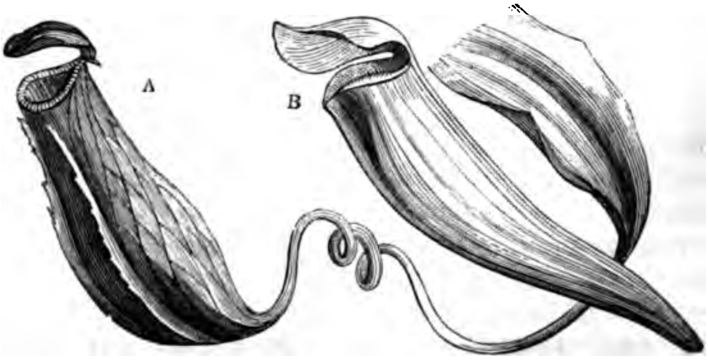
It has been said that the figure of the petiole usually approaches more or less closely to the cylindrical: this, however, is not always the case. In many plants, especially of an herbaceous habit, it is very thin, with foliaceous margins; it is then called *winged.* There are, moreover, certain leafless plants, as the greater number of species of Acacia, in which the petiole becomes so much developed as to assume the appearance of a leaf, all the functions of which it performs. Petioles of this nature have received the name of *Phyllodia* (*fig.* 57. *c*). They may always be distinguished from true leaves by the following characters: — 1. If observed when the plant is very young, they will be found to bear leaflets. 2. Both their surfaces are alike. 3. They very generally present their margins to the earth and heavens, — not their surfaces. 4. They are always straight-veined; and, as they only occur among dicotyledonous plants which have reticulated leaves, this peculiarity alone will characterise them.

But, besides the curious transformation undergone by the petiole when it becomes a phyllodium, there are several others still more remarkable: among these the first to be noticed is the *cirrhus* or *tendril* (*Capreolus* and *Clavicula* of the old botanists). It is one of the contrivances employed by nature to support plants by aid of others stronger than themselves. It was included by Linnæus among what he called *fulcra;* and has generally, even by very recent writers, been spoken of as a peculiar organ. But, as it is manifestly in most cases a particular form of the petiole, I see no reason for regarding it in any other light. It may, indeed, be a modification of the inflorescence, as in the Vine; but this is an exception, showing, not that the cirrhus is not a modification of the petiole, but that any part may become cirrhose.

In some cases the petiole of a compound leaf is lengthened, branched, and endowed with the power of twisting round any small body that is near it, as in the Pea: it then becomes what is called a *cirrhus petiolaris.* At other times, it branches off on each side at its base below the lamina into a twisting ramification, as in Smilax horrida; when it is called a *cirrhus peduncularis.* Or it passes, in the form of midrib, beyond the apex of a single leaf, twisting and carrying with it a portion of the parenchyma, as in Gloriosa superba; when it is said to be a *cirrhus foliaris.* De Candolle also refers to tendrils the acuminate, or rather caudate, divisions of the corolla of Strophanthus, under the name of *cirrhus corollaris.*

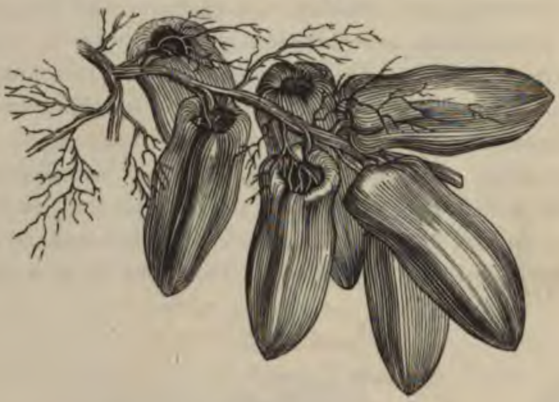
As another modification of the petiole, I am disposed to consider with Link (Elem. 202.) the singular form of leaf in Sarracenia and Nepenthes (*fig.* 58.), which has been called a *pitcher* (*Ascidium, Vasculum*). This consists of a fistular

58



green body, occupying the place and performing the functions of a leaf, and closed at its extremity by a lid, termed the *operculum*. The pitcher, or fistular part, is the petiole, and the operculum the blade of a leaf in an extraordinary state of transformation. This is found, by a comparison of Nepenthes and Sarracenia with Dionæa muscipula; in that plant the leaf consists of a broad-winged petiole, articulated with a collapsing blade, the margins of which are pectinate and inflexed. If we suppose the broad-winged petiole to collapse, and that its margins, when they meet, cohere, there would then be formed a fistular body like the pitcher of Sarracenia (*fig*. 58. B), and there would be no difficulty in identifying the acknowledged blade of the one with the operculum of the other. From Sarracenia the transition to Nepenthes (*fig*. 58. A) is obvious.

59



The student must not, however, suppose that all pitchers are petioles, because those of Nepenthes and Sarracenia are so. Those of the curious Dischidia Rafflesiana (*fig*. 59.), figured by Wallich in his *Plantæ Asiaticæ Rariores*, are leaves, the margins of which are united. The pitchers of Marcgraavia and Norantea (*fig*. 60.) are bracts in the same state.

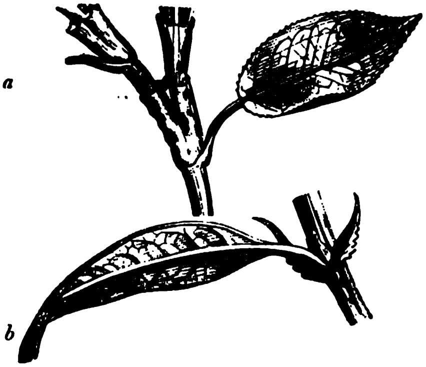
Spines of the leaves are formed either by a lengthening of the woody tissue of the veins, or by a contraction of the

60

parenchyma of the leaves: in the former case they project beyond the surface or margin of the leaf, as in many Solana and the Holly (Ilex aquifolium): in the latter they are the veins themselves become hardened, as in the palmated spines of the Barberry; the spiny petiole of many Leguminous plants is of the same nature as the latter. So strong is the tendency in some plants to assume a spiny state, that in a species of Prosopis from Chili, of which I have a living specimen now before me, half the leaflets of its bipinnate leaves have the upper half converted into spines.

2. Of Stipules.

61



At the base of the petiole, on each side, is frequently seated a small appendage, most commonly of a texture less firm than the petiole, and having a tapering termination. These two appendages are called *stipules*. They either adhere to the base of the petiole or are separate; — they either endure as long as the leaf, or fall off before it; — they are membranous, leathery, or spiny; — finally, they are entire or laciniated.

By Link they have been called *Paraphyllia*, and defined as "foliaceous parts, in structure like the leaves, and developed before those organs."

When they are membranous, and surround the stem like a sheath, cohering by their anterior margins, as in Polygonum (*fig.* 61. *a*), they have been termed *ochrea* by Willdenow. Of this the fibrous sheath at the base of the leaves of Palms, called *reticulum* by some, may possibly be a modification. In pinnated leaves there is often a pair of stipules at the base of each leaflet, as well as two at the base of the common petiole: stipules, under such circumstances, are called *stipels*.

What stipules really are is not well made out. De Candolle seems, from some expressions in his *Organographie*, to suspect their analogy with leaves; while, in other places in the same work, it may be collected that he rather considers them special organs. I am clearly of opinion that, notwithstanding the difference in their appearance, they are really accessory leaves: first, because they are occasionally transformed, in Rosa bracteata, into pinnated leaves; secondly, because they are often undistinguishable from leaves, of which they obviously perform all the functions, as in Lathyrus, Lotus, and many other Fabaceæ: and, finally, because there are cases in which buds develope in their axils, as in Salix, a property peculiar to leaves and their modifications. De Candolle, in suggesting, after Seringe, that the tendrils of Cucurbitaceæ are modified stipules, assigns the latter a tendency to a transformation exclusively confined either to the midrib of a leaf, or to a branch; and they cannot be the latter. It is, however, more probable that the tendril in this order is an accessory bud, a little out of its place, as the Bravais' have suggested. (*Ann. Sc.*, n. s., VIII. 20.)

It is sometimes difficult to distinguish from true stipules certain membranous expansions, or ciliæ, or glandular appendages of the margin of the base of the petiole, such as are found in Ranunculaceæ, Apocynaceæ, Apiaceæ, and many other plants. In these cases the real nature of the parts is only to be collected from analogy, and by comparing them with the same part differently modified in neighbouring species.

Link regards the scales of leafbuds (called by him *tegmenta*) as a kind of stipule, and such they, no doubt, sometimes are, as in Liriodendron; but then he unites with them the primordial ramentaceous leaves of Pinus, which have no analogy with stipules.

De Candolle remarks, that no Monocotyledonous plants have stipules; but they certainly exist, at least in Naiadaceæ and Araceæ. It is also said that they do not occur in the embryo; but then there are some exceptions to this statement, as well as to Miquel's remark, that they never occur upon radical leaves, *e. g.* Strawberry.

Turpin considers them of two kinds.

1. Distinct, but rudimentary, *leaves*, when they originate from the stem itself, as in Cinchonaceæ, &c.

2. *Leaflets* of a pinnated leaf, when they adhere to the leafstalk, as in Roses, &c.

The *ligula* of grasses, at the apex of their sheathing petiole, a membranous appendage, which some have considered stipulary, should rather be considered an expansion analogous to the corona of some Silenaceous plants.

It has been already noted, that when stipules surround the stem of a plant they become an *ochrea;* in this case their anterior and posterior margins are united by cohesion; a property which they possess in common with all modifications of leaves, and of which different instances may be pointed out in Magnoliaceæ, where the back margins only cohere, in certain Cinchonaceæ, in which the anterior margins of the stipules of opposite leaves are united, and in many other plants.

3. Of Bracts.

62

66

63

64

65

All the parts hitherto made the subject of inquiry are called *organs of vegetation;* their duty being exclusively to perform the nutritive parts of the vegetable economy. Those which are about to be mentioned are called *organs of fructification;* their office being to reproduce the species by a process in some respects analogous to that which takes place in the animal kingdom. The latter are, however, all modifications of the former, as will hereafter be seen, and as the subject of this division is in itself a kind of proof; bracts not being exactly either organs of vegetation or reproduction, but between the two.

Botanists call *Bracts* either the leaf from the axil of which a flower is developed, such as we find in Veronica agrestis; or else all those leaves which are found upon the inflorescence, and are situated between the true leaves and the calyx. There are, in reality, no exact limits between bracts and common leaves; but in general the former may be known by their situation immediately below the calyx, by their smaller size, difference of outline, colour, and other marks. They are often entire, however much the leaves may be divided; frequently scariose, either wholly or in part; sometimes deciduous before the flowers expand; but rarely very much dilated, as in Origanum Dictamnus, and a few other plants. It is often more difficult to distinguish bracts from the sepals of a polyphyllous calyx than even from the leaves of the stem. In fact, there is in many cases no other mode than ascertaining the usual number of sepals in other plants of the same natural order, and considering every leaf-like appendage on the outside of the usual number of sepals as a bract. In Camellia, for example, if it were not known that the normal number of sepals of kindred genera is five, it would be impossible to determine the number of its sepals. When the bracts are very small, they are called *bractlets;* or, if they are of different sizes upon the same inflorescence, the smallest receive that name. It rarely occurs that an inflorescence is destitute of bracts. In Cruciferæ this is a general character, and is observed by Link to indicate an extremely irregular structure. When bracts do not immediately support a flower or its stalk, they are called *empty* (*vacuæ*). As a general rule, it is to be understood, that whatever intervenes between the true leaves and the calyx, whatever be their form, colour, size, or other peculiarity, comes within the meaning of the term.

Under particular circumstances bracts have received the following peculiar names: —

When they are empty, and terminate the inflorescence, they form a *coma*, as in Salvia Horminum. In this case they are generally enlarged and coloured.

If they are verticillate, and surround several flowers, they constitute an *involucre*. In Apiaceous plants, the bracts which surround the general umbel are called an *universal involucre;* and those which surround the umbellules a *partial involucre*, or *involucellum*. In Compositæ, the involucre often consists of several rows of imbricated bracts, and has received a variety of names, for none of which there appears to be occasion. Linnæus called it *calyx communis*, Necker *perigynandra communis*, Richard *periphoranthium*, Cassini *periclinium*. There is often found at the base of the involucre of Compositæ an exterior rank of bracts, which Linnæus called *calyculus;* and such involucres as were so circumstanced *calyx calyculatus*. Cassini restricts the term *involucre* to this; but it seems most convenient to call these exterior bracts *bractlets*, and to say that an involucre in which they are present is *basi bracteolatum*, bracteolate at the base.

Another form of the involucre is the *cupula* (*fig.* 66.). It consists of bracts not much developed till after flowering, when they cohere by their bases, and form a kind of cup. In the Oak the cupula is woody, entire, and scaly, with indurated bracts: in the Beech it forms a sort of coriaceous, valvular, spurious pericarp: in the Hazel Nut (*fig.* 65.) it is foliaceous and lacerated.*

In Euphorbia the involucre is composed of two whorls of bracts, consolidated into a cup, and assumes altogether the appearance of a calyx, for which it was for a long time mistaken.

The name *squama* or *scale* is usually applied to the bracts of the catkin; it is also occasionally used to indicate any kind of bract which has a scaly appearance.

The bracts which are stationed upon the receptacle of Compositæ, between the florets, have generally a membranous texture and no colour, and are called *paleæ*, Englished by some botanists *chaff of the receptacle*. The French call this sort of bract *paillette*, Cassini *squamelles*.

In Palms and Araceæ there are seated, at the base of the spadix, large coloured bracts, in which the spadix, during æstivation, is wholly enwrapped, and which may perhaps perform in those plants the office of corolla. This is called the *spathe* (*fig.* 83.). Link considers it a modification of the petiole. (*Elementa*, p. 253.)

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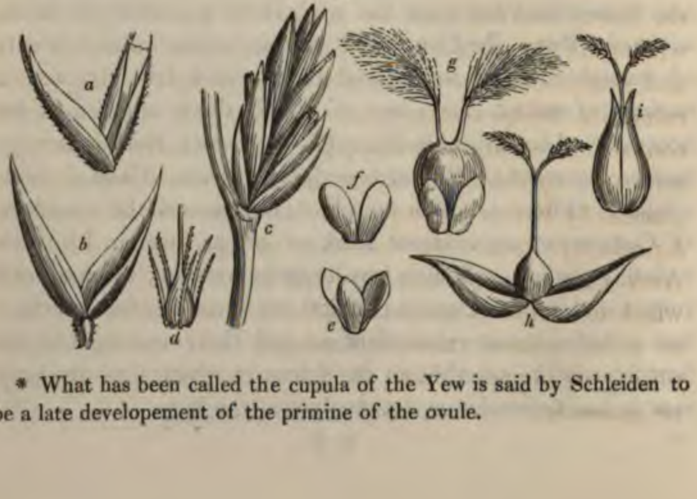

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* What has been called the cupula of the Yew is said by Schleiden to be a late developement of the primine of the ovule.

The most remarkable arrangement of bracts takes place in Grasses, in which they occupy the place of calyx and corolla, and have received a variety of names from different systematic writers. In order to explain the application of these terms, it is necessary to describe with some minuteness the structure of a *locusta* or *spikelet*, as the partial inflorescence of Grasses is denominated. Take, for example, any common Bromus; each spikelet will be seen to have at its base two opposite empty bracts (*fig.* 67. *b*), one of which is attached to the rachis a little above the base of the other: these are the *glumes* of Linnæus and most botanists, the *gluma exterior* or *calycinalis* of some writers, the *tegmen* of Palisot de Beauvois, the *lepicena* of Richard, the *cœtonium* of Trinius, and, finally, the *peristachyum* of Panzer. Above the glumes are several florets sitting in denticulations of the rachis (*fig.* 67. *c*): each of these consists of one bract, with the midrib quitting the blade a little below the apex, and elongated into a bristle called the *awn*, *beard*, or *arista*, and of another bract facing the first, with its back to the rachis, bifid at the apex, with no dorsal vein, but with its edges inflexed, and a rib on each side at the line of inflexion (*fig.* 67. *a*). These bracts are the *corolla* of Linnæus, the *calyx* of Jussieu, the *perianthium* of Brown, the *gluma interior* or *corollina* and *perigonium* of some, the *stragulum* of Palisot de Beauvois, the *gluma* of Richard, the *bale* or *glumella* of De Candolle and Desvaux, the *paleæ* of others. When the *arista* proceeds from the very apex of the bracts, and not from below it, it is denominated in the writings of Palisot a *seta*. Within the last-mentioned bracts, and opposite to them, are situated two extremely minute, colourless fleshy scales (*fig.* 67. *e*), which are sometimes connate: these are named *corolla* by Micheli and Dumortier, *nectarium* by Linnæus, *squamulæ* by Jussieu and Brown, *glumella* by Richard, *glumellula* by Desvaux and De Candolle, *lodicula* by Palisot de Beauvois, and *periphyllia* by Link. Amidst these conflicting terms it is not easy to determine which to adopt. I recommend the exterior empty bracts to be called *glumes;* those immediately surrounding the fertilising organs *paleæ ;* and the minute hypogynous ones *scales* or *squamulæ*.

The pieces of which these three classes of bracts are composed are called *valves* or *valvulæ* by the greater part of botanists; but, as that term has been thought not to convey an accurate idea of their nature, Desvaux has proposed to substitute that of *spathella*, which is adopted by De Candolle. Palisot proposed to restrict the term *glume* to the pieces of the glume, and to call the pieces of the perianthium *paleæ*. Richard called the pieces of both glume and perianthium *paleæ*, and the scales *paleolæ*. It seems to me most convenient to use the term *valvula*, because it is more familiar to botanists than any other, and because I do not see the force of the objection which is taken to it.

In the genus Carex two bracts (*fig.* 67. *i*, *h*) become confluent at the edges, and enclose the pistil, leaving a passage for the stigmas at their apex. They thus form a single urceolate body, named *urceolus* or *perigynium*. De Candolle justly observes, in his *Théorie*, that some botanists call this *nectarium*, although it does not produce honey; others *capsula*, although it has nothing to do with the fruit; but he does not seem to me more correct than those he criticises in arranging the urceolus among his miscellaneous appendages of the floral organs, which are "ni organes génitaux ni tégumens." I believe I was the first who explained the true nature of the urceolus, in my translation of Richard's *Analyse du Fruit*, printed in 1819 (p. 13.).

At the base of the ovary of Cyperaceæ are often found little filiform appendages, called *hypogynous setæ* (*fig.* 67. *d*) by most botanists, and *perigynium* by Nees von Esenbeck. These are probably of the nature of the squamulæ of Grasses, and have been named *perisporum* by some French writers.

Bracts are generally distinct from each other, and imbricated or alternate. Nevertheless, there are some striking exceptions to this; as remarkable instances of which may be cited Althæa and Lavatera among Malvaceæ, Euphorbia, all Dipsaceæ, and some Trifolia, particularly my Tr. cyathiferum, in all which the bracts are accurately verticillate, and their margins confluent, as in a true calyx.

4. Of the Flower.

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The Flower is a terminal bud enclosing the organs of reproduction by seed. By the ancients the term flower was restricted to what is now called the corolla; but Linnæus wisely extended its application to the union of all the organs which contribute to the process of fecundation. The flower, therefore, as now understood, comprehends the *calyx*, the *corolla*, the *stamens*, and the *pistil*, of which the two last only are indispensable. The calyx and corolla may be wanting, and a flower will nevertheless exist; but, if neither stamens nor pistil nor their rudiments are to be found, no assemblage of leaves, whatever may be their form or colour, or how much soever they may resemble the calyx and corolla, can constitute a flower.

We usually consider the flower to consist of a certain number of whorls, or of parts originating round a common centre from the same plane. But Adolphe Brongniart has correctly pointed out the fact that what we call whorls in a flower are in many cases not so, strictly speaking, but only a series of parts in close approximation, and at different heights upon the short branch that forms the axis. This is particularly obvious in a Cistus, where, of the five sepals, two are lower and exterior, and three higher and within the first. The manner also in which the petals overlap each other evidently points to a similar cause, although the fact of those pieces being inserted at different heights may not be apparent. (*See Ann. des Sc.* v. xxiii. p. 226.)

The flower, when in the state of a bud, is called the *alabastrus* (*bouton* of the French); a name used by Pliny for the rose-bud. Some writers say *alabastrum*, forgetting, as it would seem, that that term was used by the Romans for a scent-box, and not for the bud of a flower. Link calls the parts of a flower generally, whether united or connate, *moria*, whence a flower is *bi-polymorious* (*Elem.*, 243.); but I know of no other writer who employs these terms, which indeed are superfluous.

The flowers of a capitulum, small, and somewhat different in structure from ordinary flowers, are called *florets* (*flosculi*; *elytriculi* of Necker; *fleurons* of the French).

The period when a flower opens is called its *anthesis*; the manner in which its parts are arranged, with respect to each other, before the opening, is called the *æstivation*. Æstivation is the same to a flower-bud as vernation is to a leaf-bud: the terms expressive of its modifications are to be sought in Glossology. This term æstivation is applied separately to the parts of which a flower may consist; thus, we speak of the æstivation of the calyx, of the corolla, of the stamens, and of the pistil; but not of the æstivation of a flower collectively.

5. Of the Inflorescence.

Inflorescence is a term contrived to express generally the arrangement of flowers upon a branch or stem. The part which immediately bears the flowers is called the *pedunculus* or peduncle, and is to be distinguished from any portion of a branch by not producing perfect leaves; those which are found upon it, called *bracts*, being much reduced in size and figure from what are borne by the rest of the plant.

The normal position of the inflorescence is axillary to a leaf, the necessary consequence of its being a kind of branching. But in some plants, especially of the natural order Solanaceæ, it grows apparently opposite the leaves. It is believed that cases of such irregularity are caused by the peduncle, which is axillary to a leaf, contracting an adhesion with the internodium above it, and not separating till it is opposite the succeeding leaf. Flowers of this kind are called *oppositifolii.*

The term *peduncle,* although it may be understood to apply to all the parts of the inflorescence which bear the flowers, is practically only made use of to denote the immediate support of a single solitary flower or the whole mass of inflorescence, and is therefore confined to that part of the inflorescence which first proceeds from the stem. If it is divided, its principal divisions are called branches; and its ultimate ramifications, which bear the flowers, are named *pedicels.* There are also other names which are applied to its modifications. In plants which are destitute of stem, it often rises above the ground, supporting the flowers on its apex, as in the Cowslip. Such a peduncle is named a *scape* (*hampe,* Fr.). Some botanists distinguish from the scape the *pedunculus radicalis,* confining the former term to the peduncle which arises from the central bud of the plant, as in the Hyacinth; and applying the latter to a peduncle proceeding from a lateral bud, as in Plantago media. When a peduncle proceeds in a nearly right line from the base to the apex of the inflorescence, it is called the *rachis,* or the *axis* of the inflorescence. This latter term was used by Palisot de Beauvois to express the rachis of Grasses, and is perhaps the better term of the two, especially as the term rachis is applied by Willdenow and others to the petiole and midrib of Ferns. In the spikelets of Grasses the rachis has an unusual, toothed, flexuose appearance, and has received the name of *scobina* from Dumortier; if it is reduced to a mere bristle, as in some of the single-flowered spikelets, the same writer then distinguishes it by the name of *acicula.*

When the part which bears the flowers is repressed in its developement, so that, instead of being lengthened into a rachis, it forms a flattened area on which the flowers are arranged, it becomes what is called a *receptacle;* or, in the language of some botanists, the *receptacle of the flower* (*fig.* 72.)

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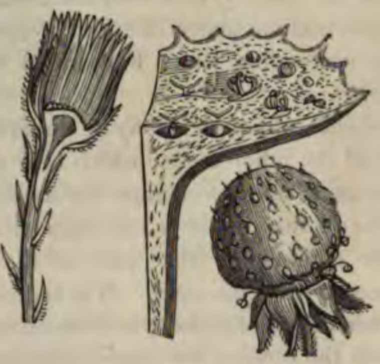

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When the receptacle is not fleshy, but is surrounded by an involucre, it has been called the *clinanthium* (the *thalamus* of Tournefort, as in Compositæ, or, in the language of Richard, *phoranthium:* Lessing calls this part the *rachis.* But if the receptacle is fleshy, and is not enclosed within an involucrum, as in Dorstenia and Ficus (*fig.* 73.), it is then called by Link *hypanthodium;* the same writer formerly named it *amphanthium*, a term now abandoned. With receptacles of this sort, which are depressed and distended branches, are not unfrequently confounded parts of a different nature, as in the Strawberry, the soft, succulent centre of which (*fig.* 74.) is evidently the growing point, excessively enlarged, and bearing the carpels upon its surface. See DISK, further on.

According to the different modes in which the inflorescence is arranged, it has received different names, the right application of which is of the first importance in descriptive botany. If flowers are sessile along a common axis, as in Plantago, the inflorescence is called a *spike* (*fig.* 76.); if they are pedicellate, under the same circumstances, they form a *raceme*, (*fig.* 77.), as in the Hyacinth: the raceme and the spike differ, therefore, in nothing, except that the flowers of the latter are sessile, of the former pedicellate. These are the true characters of the raceme and spike, which have been confused and misunderstood.

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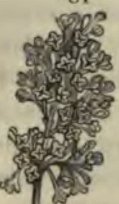

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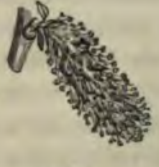

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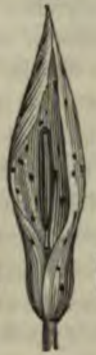

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When the flowers of a spike are destitute of calyx and corolla, the place of which is taken by bracts, and when with such a formation the whole inflorescence falls off in a single piece, either after flowering or ripening the fruit, as in Corylus, Salix, &c., such an inflorescence is called an *amentum* or *catkin* (*Catulus*, *Iulus*, *nucamentum*, of old writers (*fig*. 82.).

If a spike consists of flowers destitute of calyx and corolla, the place of which is occupied by bracts, supported by other bracts which enclose no flowers, and when with such a formation the rachis, which is flexuose and toothed, does not fall off with the flowers, as in Grasses, each part of the inflorescence so arranged is called a *spikelet* or *locusta*.

When the flowers are closely arranged around a fleshy rachis, which is enclosed in the kind of bract called a spathe (see p. 148.), the inflorescence is termed a *spadix* (*fig*. 83.).

This is only known to exist in Araceæ and Palms. It is frequently terminated, as at *fig.* 83., by a soft club-shaped mass of cellular substance which extends far beyond the flowers, and is itself entirely naked; this is an instance of a growing point analogous to what forms the spine of a branch, except that it is soft and blunt, instead of being hard and sharp-pointed.

The raceme has been said to differ from the spike only in its flowers being pedicellate: to this must be added, that the pedicels are all of nearly equal length; but in many plants, as Alyssum saxatile, the lower pedicels are so long that their flowers are elevated to the same level as that of the uppermost flowers; a *corymb* is then formed (*fig.* 87.). This term is frequently used in an adjective sense, to express a similar arrangement of the branches of a plant or of any other kind of inflorescence: thus, in Stevia, the branches are said to be *corymbose;* in others, the panicle is said to be corymbose; and so on. When corymbose branches are very loose and irregular, they have given rise to the term *muscarium;* a name formerly used by Tournefort, but not now employed.

If the expansion of an apparent corymb is centrifugal, instead of centripetal; that is to say, commences at the centre, and not at the circumference, as in Dianthus Carthusianorum, we then have the *fascicle* (*fig.* 84.); a term which may not incorrectly be understood as synonymous with *compound corymb.* The modern *corymb* must not be confounded with that of Pliny, which was analogous to our *capitulum.*

When the pedicels all proceed from a single point, as in Astrantia, and are of equal length, or corymbose, we have an *umbel* (*fig.* 80.). If each of the pedicels bears a single flower, as in Eryngium, the umbel is said to be *simple* (*fig.* 79. *a*); but if they divide and bear other umbels, as in Heracleum, the umbel is called *compound;* and then the assemblage of umbels is called the *universal umbel,* while each of the secondary umbels, or the umbellules, is named a *partial umbel.* The peduncles which support the partial umbels are named *radii.* Louis Claude Richard confined the word umbel to the compound form, and named the simple umbel *sertulum;* but this was an unnecessary change.

Suppose the flowers of a simple umbel to be deprived of their pedicels, and to be seated on a receptacle or enlarged axis, and we have a *capitulum* or head. If this is flat, and surrounded by an involucre, the compound flower, as it is inaccurately called by the school of Linnæus, of Compositæ, is produced; which is sometimes named by modern botanists *anthodium;* it is also called *cephalanthium* by Richard, *calathis* by Mirbel, *calathium* by Nees von Esenbeck. The flowers or florets borne by the capitulum in its circumference are usually ligulate, and different from those produced within the circumference. Those in the former station are called *florets of the ray;* and those in the latter, *florets of the disk.*

If all the flowers are hermaphrodite in the capitulum, it is *homogamous;* if the outer are neuter, or female, and the inner hermaphrodite, or male, it is *heterogamous;* if on the same plant some capitula are composed entirely of male flowers, and others entirely of female flowers, such a plant is termed by De Candolle *heterocephalous.*

The *glomerulus* or glomus is the same to a capitulum as the compound is to the simple umbel; that is to say, it is a cluster of capitula enclosed in a common involucre, as in Echinops.

All the forms of inflorescence which have been as yet mentioned are to be considered as reductions of the spike or raceme. Those which are now to be described are decompositions, more or less irregular, of the raceme.

The first of these is the *panicle* and its varieties. The *simple panicle* differs from the raceme in bearing branches of flowers where the raceme bears single flowers, as in Poa (*fig.* 78.); but it often happens that the rachis itself separates into irregular branches, so that it ceases to exist as an axis, as in some Oncidiums; this is called by Willdenow a *deliquescent panicle.* When the panicle was very loose and diffuse, the older botanists named it a *juba;* but this is obsolete. If the lower branches of a panicle are shorter than those of the middle, and the panicle itself is very compact, as in Syringa, it then receives the name of *thyrsus.*

Suppose the branches of a deliquescent panicle to become short and corymbose, with a centrifugal expansion indicated by the presence of a solitary flower seated in the axils of the dichotomous ramifications, and a conception is formed of what is called a *cyme*. This kind of inflorescence is found in Sambucus, Viburnum, and other plants (*fig.* 85.).

If the cyme is reduced to a very few flowers, such a disposition has been called a *verticillaster* by Hoffmansegg. (*Verzeichniss z. Pflanz. Cult.*, ii. 203.) It consitutes the normal form of inflorescence in Lamiaceæ, in which two verticillastri are situated opposite each other in the axils of opposite leaves. By Linnæus, the union of two such verticillastri was called a *verticillus* or whorl; and by others, with more accuracy, a *verticillus spurius* or false whorl. Link terms this inflorescence a *thyrsula;* but Hoffmansegg's name seems preferable.

The following tabular view of the differences in inflorescences will probably tend to render the above remarks more clear: —

- Flowers not placed on stalks,
    - arranged upon a lengthened axis,
        - which is permanent, *Spike, Locusta, Spadix.*
        - which is deciduous, *Catkin.*
    - arranged upon a depressed axis, *Capitulum, Glomerulus.*
- Flowers placed on distinct stalks,
    - arranged upon a lengthened axis.
        - Stalks simple,
            - and of equal length, *Raceme.*
            - the lowermost the longest.
                - Inflorescence centripetal, *Corymb.*
                - ———— centrifugal, *Fascicle.*
        - Stalks branched.
            - Inflorescence lengthened and centripetal, *Panicle.*
            - ———— depressed and centrifugal, *Cyme, Verticillaster.*
    - arranged upon a depressed axis, *Umbel.*

It occasionally happens, as in the Vine, that the rachis of some of the masses of inflorescence loses its flowers; but at the same time acquires the property of twining round any object within its reach, and so of supporting the stem, which is too feeble to support itself. Such rachises form what is called a spurious cirrhus, or a *cirrhus peduncularis*, and are a striking exception to the general law that the cirrhus takes its rise from the petiole or midrib.

In the preceding account of the inflorescence I have treated the subject as heretofore, because it appears upon the whole more convenient to do so for the present, notwithstanding the recent ingenious observations of the Messrs. Bravais.

These botanists, together with Messrs. Schimper and Braun, and some others, led by their examination of the spiral arrangement of leaves into an investigation of the laws that regulate the arrangement of flowers, have proposed a new nomenclature and theory, of which the following is their own abstract (*Ann. Sc.*, N. S., viii. 28.):—

I. The inflorescence is a union of flowers grouped together in mutual relation. It may often be divided into other groups, essentially homogeneous with respect to each other, and which we call *partial* inflorescences; these inflorescences may sometimes be themselves subdivided; but something arbitrary may be sometimes found in the manner of their decomposition.

II. The flowers, or partial inflorescences which perform the part of them, have two distinct modes of evolution; the centripetal and the centrifugal.

III. The SPIKE * is a centripetal inflorescence. (Plantago, Ribes, Leontodon, &c.)

IV. The COMPOUND SPIKE is centripetal, with two degrees of evolution; thus it is composed of partial inflorescences arranged centripetally, and these partial inflorescences are spikes. (Male flowers of Pinus.)

V. The CYME † is a centrifugal inflorescence. (Hemerocallis flava, Tradescantia, Strelitzia, Lamium, Cornus, Syringa.)

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* Any centripetal group whatever, such as a partial umbel, raceme, spike, capitulum, provided the peduncles are destitute of lateral bracts.

† A centrifugal group, whose peduncles grow out of each other.

VI. The THYRSE[*] is an inflorescence at first centripetal, afterwards centrifugal. (Tamus, Delphinium, Laburnum.)

VII. The SARMENTIDIUM[†] is an inflorescence of which the first evolution is centrifugal: its partial inflorescences may belong to either of the four previous forms. (Cichorium Intybus, Vitis, Geranium molle, Asclepias.)

VIII. The cyme of Monocotyledons appears to be typically *uninodal*[‡]; it is *helicoid*[§], or *scorpioid*[‖], according as its peduncles are *homodromal*[**], or *antidromal*.[††] It may be *binodal*[‡], *trinodal*[‡], *multinodal*[‡], in its first ramifications; but it has a tendency to become uninodal in its ultimate ramifications.

IX. The cyme of Dicotyledons is binodal, or multinodal; the second is sometimes a simple variety of the first. In the binodal cyme one of the nodes is homodromal, the other antidromal. These nodes have usually an unequal tendency to develope; if the homodromal node causes the abortion of its antagonist, the cyme becomes by degeneration helicoid, and scorpioid in the opposite case. The multinodal cyme offers no fixed rule in the spirals of its nodes; it generally finishes by degenerating into little binodal few-flowered or one-flowered cymes. We therefore may consider the binodal cyme as the type of the cymes of dicotyledonous plants.

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[*] A group of cymes disposed centripetally, as the flowers are in the spike.

[†] A group of cymes or spikes arranged centrifugally, as the flowers are in the cyme.

[‡] According as the peduncles bear 1, 2, or a variable number of nodes.

[§] Where the flowers are arranged in succession in a spiral around a *pseudothallus* (or axis of *uniparous*, that is one-peduncled, cymes, or sarmentidia, formed by a series of successive peduncles, fitted into each other in such a way that they seem to form but one and the same stalk, as in Hemerocallis fulva).

[‖] Where the flowers are arranged in two rows parallel to the axis of the pseudothallus, as in Canna indica.

[**] Where the direction of a spire is the same as on the central stem.

[††] Where the direction of a spire is the reverse of that on the central stem.

X. The helicoid cyme has a straight pseudothallus, not excentrical, often vertical.

XI. The scorpioid cyme has its pseudothallus rolled in a plane, excentrical, often horizontal volute, the two rows of flowers regarding the sky.

XII. A cyme may be either axillary or terminal. By decomposing the last into partial axillary cymes, we often arrive at the discovery upon the latter of the làws which the entire cyme did not offer.

XIII. The multinodal cyme, with axillary cymes, and subject to this decomposition, is sometimes rather difficult to distinguish from the thyrse. If the axillary cymes are one-flowered, there may be a difficulty in distinguishing them from the spike.

XIV. Cymes have another method of centrifugal evolution by the developement of accessory peduncles; these peduncles are of the same order as those which are born upon other nodes of the central peduncle, and are almost always antidromal.

XV. Sarmentidia follow in their organisation the same laws as the cyme.

In this memoir of the Messrs. Bravais there is much which is ingenious; but their system is founded upon theoretical refinements, which require further consideration, and much simplification, before they can be advantageously applied to practical purposes.

6. Of the Calyx.

The *calyx* is the most exterior integument of the Flower, consisting of several verticillate leaves, either united by their margins or distinct, usually of a green colour, and of a ruder and less delicate texture than the corolla.

Authors have long disputed about the definition of a calyx, and the limits which really exist between it and the corolla: the above, which is copied from Link, seems to be the only one that can be considered accurate. The fact is, that in many cases they pass so insensibly into each other, as in Calycanthus and Nymphæa, that no one can say where the calyx ends and the corolla begins, although it is evident that both are present. Linnæus, indeed, thought that it was possible to distinguish them by their position with regard to the stamens, asserting that the divisions of the calyx are opposite those organs, and of the corolla alternate with them; but, if this distinction were admitted, the corolla of the Primrose would be an inner calyx, which is manifestly an absurdity. Jussieu defines a calyx by its being continuous with the peduncle, which the corolla never is; and this may seem in some cases a good distinction: but there are plenty of true calyxes, of all Papaveraceous and Cruciferous plants, for instance, in which the calyx is deciduous, and not more continuous with the peduncle than the corolla itself. The only just mode of distinguishing the calyx seems to me to be to consider it in all cases the most exterior verticillate series of the integuments of the flower within the bracts, whether it be half-coloured, deciduous, and of many pieces, as in Brassicaceæ; membranous and wholly-coloured, as in Mirabilis; green and campanulate, or tubular, as in Laurus and Lythrum. Upon this principle, whenever there is only one series of floral integuments, that series is the calyx. A calyx, therefore, can exist without a corolla; but a corolla cannot exist without a calyx, either perfect or rudimentary.

The term Perianth is sometimes given as synonymous with calyx; but this is an error.

The word Perianth signifies the calyx and corolla combined, and is therefore strictly a collective term. It should only be employed to designate a calyx and corolla, the limits of which are undefined, so that they cannot be satisfactorily distinguished from each other, as in most Monocotyledonous plants, the Tulip and the Orchis for example. But since, even in such plants as these, there can be no reasonable doubt that the three outer floral leaves are the calyx, and the three inner the corolla (as is shown both by Tradescantia and its allies, in which the usual limits between calyx and corolla exist, and also by the usual origin of those parts in two distinct whorls), the utility of the term Perianth is rendered extremely confined. It is often a mere evasion of the task of ascertaining the exact nature of the floral envelopes in doubtful cases. Some writers, among whom are Link and De Candolle, have substituted *Perigonium* for Perianthium: but the latter is in most common use, its application is well understood, and there is no good reason for its being changed. Ehrhart, with whom the name Perigonium originated, called it double when the calyx and corolla are evidently distinct, and single if they are not distinguishable: but this use of terms is obsolete.

The divisions of a calyx are called its *sepals* (*sepala*); a term first invented by Necker, and revived by De Candolle. Botanists of the school of Linnæus call them the leaflets or foliola. Link says the word sepalum is barbarous, and proposes to substitute *phyllum.* The sepals are generally longer than the corolla in æstivation, and during that period act as its protectors: during flowering they are mostly shorter.

The calyx, in ordinary cases, if deciduous, falls off from the peduncle by its base. In many cases the sepals drop off separately, as leaves fall from the stem; but occasionally they cohere firmly into a sort of cap or lid, which is pushed off entire by the increase of the corolla and stamens: in these cases the calyx is said to be *operculate*, if it falls off without any lateral rupture of its cap, as in Eucalyptus; and *calyptrate*, if at the period of falling it bursts on one side, as in Eschscholtzia. In the former of these two cases, the cohesion between the sepals is complete and never destroyed; in the latter, two of the sepals separate, the cohesion between the remainder continuing complete.

The calyx of Compositæ is so very different in appearance from the calyx of other plants, that it is known by the particular name of *pappus.* It usually consists of hair-like processes proceeding from the apex of the ovary, in which case it is said to be *pilose*: if those hairs are themselves divided, it is *plumose*; if they are very unusually stiff, it is *setose*, in which case the setæ are often reduced in number to two, or even one; if the divisions of the pappus are broad and membranous, it is said to be *paleaceous:* finally, it is sometimes reduced to a mere rim: in which case it is said either to be *marginate*, or to be *none* — to have no existence. A calyx appears to be brought into this state by having no room to develope, in consequence of the pressure of the surrounding flowers. In such cases as this, where the calyx is altogether obsolete, the definition of that organ, as the most external of the floral envelopes, appears to be destroyed: but there can be no doubt that it is present in the form of a membrane adhering to the side of the ovary, although it is not visible to our eyes. The same may be said of such plants as those Acanthaceæ (*Introduction to the Nat. Syst.*, p. 233.), in which, although the calyx is reduced to a mere ring, yet it does exist in the shape of that ring.

The Calyx being composed of leaves analogous to those of the stem, but reduced in size and altered in appearance, it will follow that it is subject to the same laws of developement as stem-leaves; and, as the latter, in all cases, originate immediately from the axis, *below* those that succeed them in the order of developement, so the calyx must always have an origin beneath those other organs which succeed it in the form of corolla, stamen, and pistil or ovary. Hence has arisen the axiom in botany, that whatever the apparent station of the calyx may be, it always derives its origin from below the ovary: nevertheless, it is often said to be superior.

If it is distinct from the ovary, as in Silene, it is said to be *inferior* or *adherent* (*calyx inferus*, or *liberus*); and the ovary is then called *superior* (*ovarium superum*, or *liberum*) (Plate V. fig. 3.); but if it is firmly attached to the sides of the ovary, so that it cannot be separated, as in Myriophyllum, it is then called *superior*, or *free* (*calyx superus*, or *liberus*), and the ovary *inferior* (*ovarium inferum*) (Plate V. fig. 7. 9.). From what has been said of pappus it will be obvious that it is a *superior calyx.*

The general opinion of botanists, in regard to the real nature of the superior calyx, is such as I have stated; and the accuracy of it in the majority of cases is indisputable: but it is by no means certain that, in some instances, what is called the tube of the calyx is not, as I have elsewhere stated

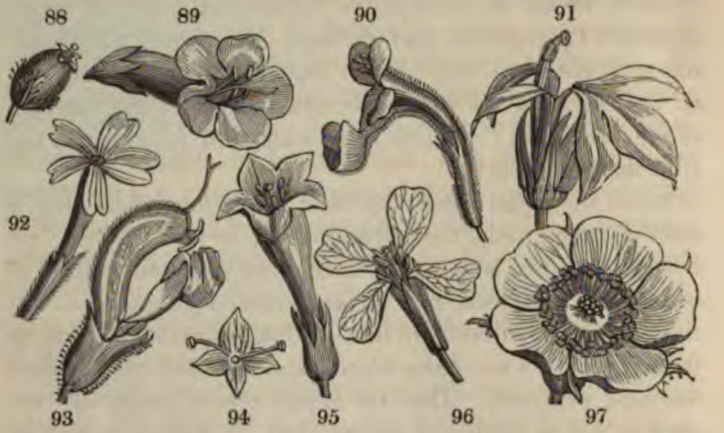
(*Introduction to the Natural System*, p. 26.), "sometimes a peculiar extension or hollowing out of the apex of the pedicel, of which we see an example in Eschscholtzia, and of which Rosa and Calycanthus, and, perhaps, all supposed tubes without apparent veins, may also be instances." And if this be so, the calyx may be superior in consequence of the cohesion of the ovary with the inside of an excavated pedicel, and not with the calyx itself.

When the sepals cohere by their contiguous edges into a kind of tube or cup, the calyx is said to be *monophyllous;* an inaccurate term, which originated when the real nature of organs was unknown, and when a monophyllous calyx was thought to consist really of a single leaf, clipped into teeth at its margin. To avoid this inaccuracy, the word *gamosepalous* has been proposed. That the sepals are originally all distinct is not a matter of theory, but, as Schleiden rightly observes, of investigation to be established by actual evidence.

Various terms are employed to express the degree in which the sepals of a monophyllous calyx cohere: they will be explained in Glossology. When no cohesion whatever takes place between the leaves of a calyx, the term *sepalous* is employed with that Greek numeral prefixed, which is equivalent to the number of pieces; as, for example, if they are two, the calyx is disepalous; if three, trisepalous; if four, tetrasepalous, and so on.

Sometimes the calyx has certain expansions or dilatations, as in Scutellaria and Salsola. These are generally named *appendages*, and such a calyx is said to be *appendiculate;* but Mœnch has proposed a particular term for them, *peraphyllum*, which is, however, never used.

7. Of the Corolla.



That envelope of the flower which forms a second whorl within the calyx, and between it and the stamens, is called the *corolla*. Its divisions always, without exception, alternate with those of the calyx, and are called *petals*. Like the sepals, they are either united by their margins, or distinct; but, unlike the calyx, they are rarely green, being for the most part either white, or of some colour, such as red, blue, or yellow, or of any of the hues produced by their intermixture. The corolla is generally also larger than the calyx.

Necker called the corolla *perigynandra interior*, and Linnæus occasionally gave it the name of *aulæum*, a term literally signifying the drapery of a room.

The alternation of the segments of the corolla with those of the calyx is a necessary consequence of their both being modifications of whorls of leaves, and therefore subject to the same laws of arrangement. If two whorls of leaves are examined, those of Galium, for example, they will always be found to be mutually so arranged, that if the internode which separates them were removed, they would exactly alternate with each other; and as there are no known exceptions to this law in real leaves, it is natural that it should not be departed from in any modifications of them.

When the petals of a corolla are all distinct, then the corolla is said to be *polypetalous;* but if they cohere at all by their contiguous margins, so as to form a tube, it then becomes what is called *monopetalous;* an innacurate term of the same origin as that of monophyllous, in regard to calyx (*see* p. 165.), and for which that of *gamopetalous* has been sometimes substituted.

If the petals adhere to the bases of the stamens, so as to form a sort of spurious monopetalous corolla, as in Malva and Camellia, such a corolla has been occasionally called *catapetalous;* but this term is never used, all such corollas being considered polypetalous.

When the petals are confluent into a monopetalous corolla, they constitute what is called a *tube;* the orifice of which is the *faux* or *throat.* The principal forms of such a corolla are rotate (*fig.* 94.), hypocrateriform (*fig.* 92.), infundibuliform (*fig.* 95.), campanulate (*fig.* 96.), and labiate (*fig.* 93.). When the divisions of a monopetalous corolla do not, as in Campanula, spread regularly round their centre, but part take a direction upwards, and the remainder a direction downwards, as in Labiatæ, the upper form what is called the *upper lip*, and the lower, the *lower lip*, or *labellum;* the latter term is chiefly applied to the lower lip of Orchidaceous plants. If the upper lip is arched, as in Lamium album, it is termed the *galea* or *helmet.* When the two lips are separated from each other by a wide regular orifice, as in Lamium, the corolla is said to be *labiate* or *ringent;* if the upper and lower sides of the orifice are pressed together, as in Antirrhinum, it is *personate* or *masked*, resembling the face of some grinning animal. In the latter the lower side of the orifice is elevated into two longitudinal ridges, divided by a depression corresponding to the sinus of the lip; this part of the orifice is called the *palate.* In ringent and personate corollas the orifice is sometimes named the *rictus;* but this term is superfluous and little used.

A petal consists of the following parts: — the *limb* or *lamina;* and the *unguis* or *claw.* The claw is the narrow part at the base which takes the place of the foot-stalk of a leaf, of which it is a modification; the limb is the dilated part supported upon the claw, and is a modification of the blade of a leaf. In many petals there is no claw, as in Rosa; in many it is very long, as in Dianthus. When the claw is present, the petal is said to be *unguiculate*. In some unnaturally deformed flowers the limb is absent, as in the garden variety of Rose, called R. Œillet, in which the petals consist wholly of claw.

According to the manner in which the petals of a polypetalous corolla are arranged, they have received different names, which are thus defined by Link: — the *rosaceous* corolla (*fig.* 97.) has no claw, or it is very small; the *liliaceous* (*fig.* 71.) has its claws gradually dilating into a limb, and standing side by side; a *caryophyllaceous* has long, narrow, distant claws; the *alsinaceous* has short distant ones; the *cruciate* flower has four valvaceous sepals, four petals, and six stamens, of which two are shorter than the rest, and placed singly in front of the lateral sepals, and four longer, and standing in pairs opposite the two other sepals. If the corolla is very irregular, with one petal very large and helmet-shaped, or hooded, as in Aconitum, it is sometimes called *cassideous;* if it resembles what is called labiate in monopetalous corollas, it is termed *labiose*. The corolla of the Pea, and most Leguminous plants, has received the fanciful name of *papilionaceous* or *butterfly-shaped*, (*figs.* 98, 99.); in this there are five petals, of which the upper is erect and more expanded than the rest, and is named the *standard* or *vexillum;* the two lateral are oblong, at right angles with the standard, and parallel with each other, and are called the *wings* or *alæ;* and the two lower, shaped like the wings and parallel with them, cohere by their lower margin, and form the *keel* or *carina*. The wings were formerly called *talaræ* by Link, and the keel *scaphium* by the same author.

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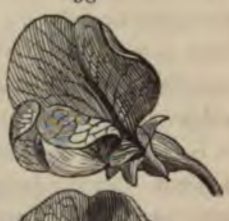

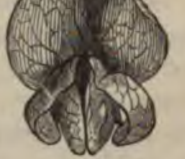

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When the corolla is very small, or when it forms a part of a capitulum, it is called *corollula:* that of a floret is so called.

If the flower has no corolla, it is said to be *apetalous*.

Sometimes a petal is lengthened at the base into a hollow tube, as in Orchis, &c.: this is called the spur or *calcar*, and by some *nectarotheca*.

In Umbelliferæ the petal is abruptly acuminate; and the acumen is inflexed. The latter is named the *lacinula*.

A corolla is said to be *regular* when its segments form equal rays of a circle supposed to be described with the axis of the flower for a centre. If they are unequal, the corolla is called *irregular*. *Equal* and *unequal* are occasionally substituted for regular and irregular.

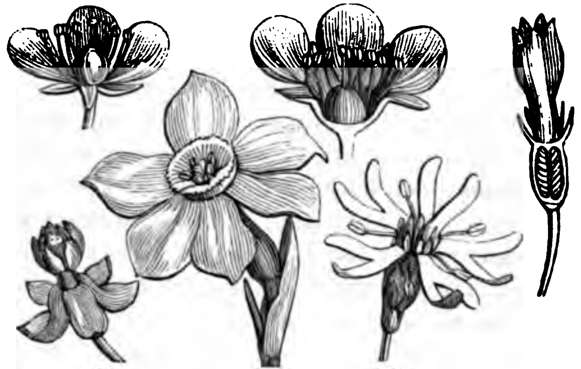
In anatomical structure, the petal should agree with a leaf, of which it is a mere modification; and, in fact, it does so in all that is important, its differences consisting chiefly in a diminished size, an attenuation and colouring of the tissue, with a suppression of the pleurenchyma. Like a leaf, petals consist of a flat plate of parenchyma, articulated with the stem, traversed by veins, and frequently having stomates upon its surface. Their veins consist almost entirely of delicate spiral vessels, upon which the parenchyma is immediately placed. It is therefore by mistake that De Candolle has stated (*Organogr.*, p. 454.) that stomates and spiral vessels are usually absent.

The petals are usually deciduous soon after flowering, or even at the instant of expansion; a very rare instance of their persistence and change from minute colourless bodies into leafy, richly coloured expansions, occurs in Melanorrhæa usitatissima.

Their colours are due to the secretion within the bladders of their parenchyma of a peculiar substance: even white petals are so in consequence of the deposit of an opaque white substance, and not because of the absence of colouring matter.

In most corollas the petals, in their natural state, form but one whorl, within that of the calyx: but instances exist in which they naturally are found in several whorls, as in Nymphæa, Nuphar, Magnolia, &c. It sometimes happens that, if there is more than one row of petals, all within the first row assume a different appearance from the first; the filamentous processes of the crown of Passiflora are also apparently of this nature.

The petals are often furnished with little appendages (*fig.* 105.), which are either inner rows of petals in a state of adhesion to the first row, or modified stamens; which it is sometimes difficult to ascertain. Many of these enter into Linnæus's notion of *nectarium*, although nearly the whole of them are destitute of any power of secreting *nectar* or honey.



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The most common form of appendage is the *corona*, which proceeds from the base of the limb, forming sometimes an undivided cup, as in Narcissus (*fig.* 104.), when it becomes the *scyphus* of Haller; sometimes dividing into several foliaceous erect scales, as in Silene and Brodiæa, when it forms the *lamella* of some writers; occasionally appearing as cylindrical or clavate processes, as in Schwenckia and Tricoryne, where it is manifestly modified stamens; and even in some instances forming a thick solid mass covering over the ovarium, and adhering to the stamens, as in Stapelia; when it is called the *orbiculus*. Parts of this last form of corona bear several names, which are found useful in avoiding repetition in describing the complicated structure of this kind of appendage. The whole mass of the corona is the *orbiculus*, or *saccus*, or *stylotegium;* certain horn-like processes are *cornua*, or horns; the upper end of these is the beak, or *rostrum*, and their back, if it is dilated and compressed, is the *ala*, or *appendix;* occasionally there is an additional set of horns proceeding from the base of the orbiculus, and alternate with the *horns*, these are *ligulæ;* the circular space in the middle of the top of the orbiculus is the *scutum.* Brown names the orbiculus *corona staminea*, and its divisions *foliola*, or leaflets.

In some plants, as Cynoglossum, the lamellæ are very small, scale-like, and overarch the orifice of the tube; such have received the name of *fornix.*

Link calls every appendage which is referable to the corolla a *paracorolla;* or, if consisting of several pieces, *parapetalum;* and every appendage which is referable to the stamens a *parastemon.* The filiform rays of the corona of Passiflora the same author calls *paraphyses* or *parastades.*

Mœnch names such appendages of the corolla as the filamentous beard of Menyanthes *perapetalum*, and Sprengel calls the same thing *nectarilyma.*

In Ranunculus there exists at the base of each petal a little shining, sometimes elevated, space which secretes honey. This is the true *nectarium* or *nectarostigma* of Sprengel. By some writers it has been considered a kind of reservoir, in which there is some plausibility; but it seems to me, from analogy, to be a barren stamen, united with the base of the petal, and to be of the same nature as the lamella of other plants.

8. Of the Stamens.

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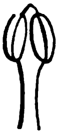

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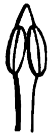

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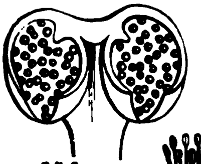

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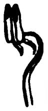

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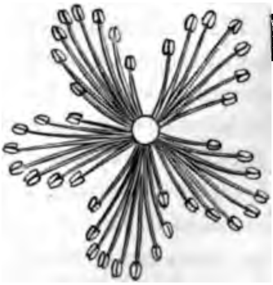

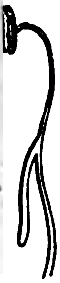

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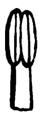

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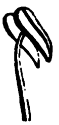

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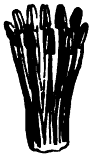

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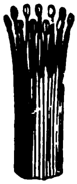

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Next the petals, in the inside, are seated the organs called *Stamens* — the *Apices* of old botanists. These constitute the *Andrœceum* or male apparatus of the flower, like the calyx and corolla are modifications of leaves, and consist of the *filament*, the *anther*, and the *pollen*, of which the two latter are essential: the first is not essential; that is to say, a stamen may exist without a filament, but it cannot exist without an anther and pollen. All bodies, therefore, which resemble stamens, or which occupy their place, but which are destitute of anther, are either petals, or appendages of the petals, or abortive stamens.

As the petals are naturally alternate with the sepals, so the natural station of the stamens, if of equal number with the petals, is alternately with them; and all deviations from this law are to be understood as irregularities arising from the suppression or addition of parts. Thus, when in the Primrose we find the stamens opposite the segments of the corolla, and equal to them in number, it is to be supposed that those stamens which are present constitute the second of two rows of which the exterior is not developed; and when in Silene we find the stamens ten, while the petals are five, the former are to be considered to consist of two rows, although appearing to consist of one. This may be understood by examining Oxalis, in which the stamens are all apparently in one row, but are alternately of different lengths. When the number of stamens exceeds twice that of the petals, they will still be divisible by the number of which they were at first a multiple, until their number is excessively increased, when they seem to cease to bear any kind of proportion to the petals.

The stamens always originate from the space between the base of the petals and the base of the ovary. But botanists are nevertheless in the habit of saying that they are inserted into the calyx or corolla (*fig.* 120.) (*perigynous*), or under the pistil (*fig.* 118.) (*hypogynous*), or into the pistil (*fig.* 119.) (*epigynous*), all which expressions are inaccurate, and lead to erroneous notions of structure. The student, therefore, must understand, that when in the Primrose the stamens are said to be inserted

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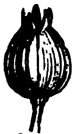

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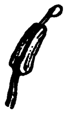

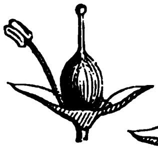

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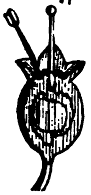

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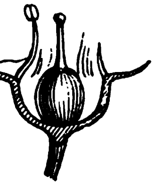

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into the mouth of the corolla, it is meant that they cohere with the corolla as far as the mouth, where they first separate from it; when in the Rose they are said to be inserted into the calyx, it is meant that they cohere with the calyx up to a certain point, where they separate from it; when in Arabis they are said to be inserted under the pistil, it is meant that they cohere with neither calyx nor corolla, but stand erect from the point which immediately produces them; and finally, when in Orchis or Heracleum they are said to be inserted into the pistil, such an expression is to be taken as meaning that they cohere with the pistil more or less perfectly. For excellent arguments in support of this hypothesis, see Dunal's *Considérations sur la nature et les rapports de quelques uns des Organes de la Fleur.* I do not use them, or any such, here, because it seems to be so self-evident a fact, when once pointed out, as to require no demonstration, and can easily be ascertained to be true by actual inspection of a flower in its different stages of growth.

When the filaments are combined into a single mass, the mass is said to be a brotherhood or an *adelphia:* if there is one combination, as in Malva, they are *monadelphous* (*fig.* 114.); if two, as in Fumaria or Pisum, *diadelphous;* if three, as in some Hypericums, *triadelphous;* if several, as in Melaleuca, *polyadelphous* (*fig.* 112.). The tube formed by the union of the filaments in a monadelphous combination is called, by Mirbel, *androphorum.*

If the stamens are longer than the corolla they are *exserted;* if shorter, they are called *included:* when they all bend to one side, as in Amaryllis, they are *declinate;* if two out of four are shorter, they are *didynamous;* if four out of six are longest, they are *tetradynamous.*

The *number* of stamens is indicated by a Greek numeral prefixed to the word *androus*, which signifies male, thus: —

One stamen is Monandrous.
Two — Diandrous.
Three — Triandrous.
Four — Tetrandrous.
Five — Pentandrous.
Six — Hexandrous.
Seven — Heptandrous.
Eight — Octandrous.
Nine — Enneandrous.
Ten — Decandrous.
Eleven or twelve stamens, Dodecandrous.
Twelve to twenty — Icosandrous.
Above twenty — Polyandrous or Indefinite.

The *filament* (Plate III.) (*capillamentum*, or *pediculus*, of some) is the part that supports the anther. It consists of a bundle of delicate woody tissue and spiral vessels, surrounded by cellular tissue, and is in all respects the same as the petiole of a leaf, of which it is a modification, except that its parts are more delicate. As the petiole is unessential to the leaf, so is the filament to the anther, it being frequently absent, or at least so strictly united to the sides of the calyx or corolla as to be undistinguishable. Its most common figure is filiform or cylindrical (Plate III. fig. 12, 13. 20, 21.), and it is almost always destitute of colour; but there are exceptions to both these characters. In Fuchsia, for instance, the filaments are red like the petals; in Adamia they are blue; in Œnothera they are yellow; and a return to the foliaceous state of which they usually are a distinct modification is by no means rare. (Plate IV. fig. 6. 8.) Thus the filament in Canna is undistinguishable from petals except by its having an anther; in the same genus and its allies, and in all Zingiberaceæ, the inner series of what seem to be petals are modifications of filaments (see *Introduction to the Nat. Syst.*, ed. 2. p. 325.): and this is a very common circumstance in sterile stamens.

The filament also varies in other respects: in Thalictrum it is thickest at the upper end, or *clavate* (Plate III. fig. 23.); in Mahernia *geniculate* (Plate III. fig. 25.), in Hirtella *spiral*, in Crambe *bifurcate*, in Anthericum *bearded* or *stupose*. In some plants the filaments are combined into a solid body called the *columna*, as in Stapelia, Stylidium (Plate IV. fig. 1, 2, 3.), Rafflesia, and others: this has in Orchidaceæ received from Richard the name of *gynostemium*.

Care must be taken not to confound the pedicel and single stamen of the naked male flowers of Euphorbia with a filament, as was done by all writers, until Brown detected the error. For modifications of filaments see Plates III. and IV.

The Anther (*Theca* of Grew; *Capsula*, Malpighi; *Apex*, Ray; *Testiculus* or *Testis*, Vaillant; *Capitulum*, Jungius; *Spermatocystidium*, Hedwig) is a body generally attached to the apex of the filament, composed of two parallel lobes or cells (*thecæ*, or *coniothecæ*, or *loculi*,) containing *pollen*, and united by the *connective*. It consists entirely of cellular tissue, with the exception sometimes of a bundle of very minute vascular tissue, which diverges on each side from the filament, and passes through that part of the anther from which the pollen has been incorrectly supposed to separate, and which is called the *receptacle* of the *pollen* by some, the *trophopollen* by Turpin, and the *raphe* by Link, but with greater propriety the *septum* of the anther. Its coat is called by Purkinje *exothecium*.

In the most common state of the anther the cells are parallel with each other (Plate III. fig. 14.), and open with two *valves* (Plate III. fig. 13. *a*), by a longitudinal fissure from the base to the apex; in Labiatæ and Scrophulariaceæ the cells diverge more or less at the base (Plate III. fig. 15, 18.), so as in some cases to assume the appearance of a one-celled horizontal anther, especially after they have burst. In Cucurbitaceæ the lobes are very long and narrow, sinuous, and folded back upon themselves (Plate III. fig. 24.). In Salvia the connective divides into two unequal portions, one of which supports a cell and the other is cell-less; in this case the connective has been called by Richard, *distractile*. Lacistema (Plate IV. fig. 7.) affords another instance of a divided connective. In many of the cases of excessive divergence of the cells the line of dehiscence of the anther is changed from longitudinal to vertical (Plate III. fig. 20. 17.), and has actually been supposed to be really transverse; an error which in most cases has arisen from not understanding the real structure of the anther. Some anthers, however, no doubt have cells that burst transversely, as Lemna, Alchemilla arvensis, Securinega, &c. (See Plate III. fig. 12. 16. 30.)

All anthers are not two-celled, their internal structure being subject to several modifications. It sometimes happens that the anther is four-celled, as in Tetratheca. In Epacris the two ordinary cells become confluent into one, and the anther is therefore one-celled. In Maranta and Canna only one cell is produced, the other being entirely suppressed. In most Amarantaceæ, and some other plants, the anther seems to be absolutely one-celled. (Plate IV. fig. 8.)

Of all these the four-celled anther is the type, and both the one-celled and two-celled are probably mere modifications of it, depending upon whether the septa which originally exist all remain complete, or are half absorbed, or wholly absorbed. Schleiden says he has found the anther before its bursting quadrilocular in more than one hundred families; amongst which may be named Graminaceæ, Cyperaceæ, Liliaceæ, Labiatæ, Borraginaceæ, Scrophulariaceæ, Compositæ, Apiaceæ, Ranunculaceæ, with its allies, Rosaceæ (Juss.), and Leguminosæ, which orders alone constitute almost one half of the entire vegetation of the globe. It has been often asserted, he says, that the anther could not originally be quadrilocular, because it opens by two fissures only; which is as much as to consider two rooms in a house as one, because they have not folding doors, but single doors placed close together. Properly speaking, every anther really opens with four fissures; they appear, however, only as two, because each pair lies at the side of the common septum.

Other deviations from the normal form of anther occur, which are less easy to reconcile with the idea of a two-celled type. In some Lauraceæ the anther is divided into four cells, one placed above the other in pairs; in Ægiceras it consists of numerous little cavities; and in the singular genus Rafflesia the interior is separated into many cellules of irregular figure and position, described by Brown as "somewhat concentrical, longitudinal, the exterior ones becoming connivent towards the apex, sometimes confluent, and occasionally interrupted by transverse partitions." In these instances the septa may be understood to arise from portions of the cellular tissue of the anther remaining unconverted into pollen.

With regard to deviations from the usual mode of dehiscence, Brown observes (*Linn. Trans.* xiii. 214.), "that they are numerous: in some cases consisting either in the aperture being confined to a definite portion, — generally the upper extremity of the longitudinal furrow, — as in Dillenia and Solanum; in the apex of each theca being produced beyond the receptacle of the pollen into a tube opening at top, as in several Ericaceæ (Plate III. fig. 22.); or in the two thecæ being confluent at the apex, and bursting by a common foramen or tube, as in Tetratheca (see Plate IV. fig. 4.). In other cases a separation of determinate portions of the membrane takes place, either the whole length of the theca, as in Hamamelaceæ and Berberaceæ, or corresponding with its subdivisions, as in several Lauraceæ, or lastly, having no obvious relation to internal structure as in certain species of Rhizophora." In Lauraceæ and Berberaceæ the anthers are technically said to burst by valves (Plate IV. fig. 10, 11.), that is to say, the dehiscence does not take place by a central line, but the whole face of the cell separates from the anther, and curls backwards, adhering to it only at the apex, to which it is, as it were, hinged.

In Rhizophora, above alluded to, the anther is said by Mr. Griffith to be compressed, with the edges anterior and posterior, and to open by the separation of a valve from the sides, when the pollen is seen lying in alveolar excavations, the upper portions of which may be traced on the inner face of the valves. (*Trans. Med. & Phys. Soc. Calcutta.*) Mr. Griffith rightly explains this singular structure as a modification of dehiscence, caused by the adhesion of the valves to each other at the usual line of fissure, and their separation from the connective. It is not therefore quite correct to say that the dehiscence of Rhizophora bears no obvious relation to internal structure; it is of the same nature as that of Lauraceæ, Berberaceæ, &c., and is analogous to the disarticulation of the valves of Brassicaceous plants.

The cells of the anther have frequently little appendages, as in different species of Erica, when they resemble setæ, aristæ, or crests. (Plate III. fig. 29.)

The anthers are attached to the filament either by their base, when they are called *innate* (Plate III. fig. 27. 21. 23.), or by their back, when they are *adnate* (Plate III. fig. 13.), or by a single point of the connective from which they lightly swing: in the latter case they are said to be *versatile*. This form is common to all true Grasses.

When the line of dehiscence is towards the pistil, the anthers are called by Brown *anticæ*, but by other botanists *introrsæ*, or turned inwards: when the line is towards the petals, they are said by Brown to be *posticæ*, and by other botanists to be *extrorsæ*, or turned outwards.

The *connective* is usually continuous with the filament, and terminates just at the apex of the anther; but in some plants, as Compositæ, it is articulated with the filament (Plate IV. fig. 5.). In others it is lengthened far beyond the apex (Plate IV. fig. 6. 9.), now into a kind of crest, as in many Zingiberaceæ; now into a sort of horn, as in Asclepiadaceæ; now into a kind of secreting cup-like body articulated with the apex, as in Adenostemon. Very frequently it is enlarged in various ways. For cases of this kind, see Plates III. and IV. Its being sometimes two-lobed, or forked, has been already noticed (Plate IV. fig. 7.). The lining of the anther has received particular illustration from Purkinje, who calls it *endothecium*, and who has found that it consists of that very remarkable kind of tissue, which has been already described under the name of fibro-cellular. According to that botanist the forms of this tissue are extremely variable, the vesicles being sometimes oblong, sometimes round, frequently cylindrical, usually fully developed, or, in some cases, merely rudimentary; the vesicles are in some species erect, in others decumbent, but in all cases more or less fibrous. (See Plate I. figs. 4. 13, 14, 15. 18, 19, 20.). For an elaborate treatise on the subject, see Joh. Ev. Purkinje *de Cellulis Antherarum Fibrosis:* Vratislaviæ, 1830, 4to; with eighteen plates.

The stamen deviates in a greater degree than any other organ from the structure of the leaf, by a modification of which it is produced; and, at first sight, in many cases, it appears impossible to discover any analogy between the type and its modification; as, for instance, between the stamen and leaf of a Rose. Nevertheless, if we watch the transitions which take place between the several organs in certain species, what was before mysterious, or even inscrutable, becomes clear and intelligible. In Nymphæa alba the petals so gradually change into stamens, that the process may be distinctly seen to depend upon a contraction of the lower half of a petal into the filament, and by a developement of yellow matter within the substance of the upper end of the same petal on each side into pollen. A similar kind of passage from petals to stamens may be found in Calycanthus, Illicium, and many other plants. Now, as no one can doubt that a petal is a modified leaf, it will necessarily follow, from what has been stated, that a stamen is one also. But it is not from parts in their normal state that the best ideas of the real nature of the stamen may be formed; it is rather by parts in a monstrous state, when reverting to the form of that organ from which they were transformed, that we can most correctly judge of the exact nature of the modification. Take for example that well-known double Rose, called by the French R. Œillet. In that very remarkable variety, the claw of the petals may at all times be found in every degree of gradation from its common state to that of a filament, and the limb sometimes almost of its usual degree of developement, — sometimes contracting into a lobe of the anther on one side, or perhaps on both sides, — now having the part that assumes the character of the anther merely yellow, — now polliniferous, — and finally acquiring, in many instances, all the characters of an undoubted though somewhat distorted stamen. Double Pæonies, Double Tulips, and many other monstrous flowers, particularly of an icosandrous or polyandrous structure, afford equally instructive specimens. It is for these reasons that it is stated in the *Outlines of the first Principles of Botany*, 307., that "the anther is a modification of the lamina, and the filament of the petiole."

I ought, perhaps, to have put the explanation in a more extended form. A leaf consists of a midrib, on each side of which is a parenchymatous expansion, consisting of a double stratum of tissue, separated by vessels. In the anther the midrib assumes the form of the connective; the double stratum on each side of the midrib is, at the centre, developed in the form of pollen, and hence the primitive quadrilocular structure of the anther, as above described. The line of dehiscence in ordinary circumstances is the margin of the modified leaf. Schleiden makes this additional remark:— "The normal leaf, as is well known, exhibits upon its upper surface cellular tissue, different in structure from that on the under; to this we find that the pollen of the anterior and posterior cells of the anther corresponds. It may, perhaps, be possible, and certainly not uninteresting, to ascertain, by experiment, whether or not the pollen of one of these compartments only possesses the external characters* of pollen, and likewise different functions in the process of impregnation, or whether in diœcious plants one kind would produce male, the other female embryos."

Agardh considers a stamen to be composed of two leaves in a state of adhesion; and that it is in fact a bud axillary to a sepal or petal. This is very nearly the opinion formerly entertained by Wolff. Endlicher adopts this view to a certain extent; and supposes the leaves to be rolled backwards, so that their under surface becomes the polliniferous part. But all this is mere hypothesis, unsupported by evidence, and in opposition to the direct observations of Mirbel and Schleiden. The latter well observes, that the stamens are evidently modified simple leaves, for they constantly appear at a later period than the petals, although they afterwards develope themselves more rapidly; they stand at first higher up upon the axis than the preceding circle of corollary leaves, and they alternate invariably with them.

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* It is so expressed in the translation in Taylor's Magazine; in the original it is: "ob vielleicht der pollen einer von beiden, nur der form nach pollen sei, und bei der befruchtung sich verschieden verhalte," u. s. w.

Such is the structure of the stamens in their perfect state. It often, however, happens that, owing to causes with which we are unacquainted, some of the stamens are developed imperfectly, without the anther and pollen. In such cases they are called *sterile stamens* (*parastemones* Link), and are frequently only to be recognised by the position they bear with respect to the other parts of the flower. Botanists consider every appendage, or process, or organ, which forms part of the same series of organs as the true stamens, or which originates between them and the pistil, as stamens, or as belonging to what Röper calls the *andrœceum*, namely, to the *male system;* and every thing on the outside of the fertile stamens is in like manner often referred to modifications of petals, a remarkable instance of which is exhibited by Passiflora. There is however no certain rule by which it can be determined whether such bodies belong to the stamens or petals.

The appearances assumed by these sterile stamens are often exceedingly curious, and generally very unlike those of the fertile stamens; thus in Canna they are exactly like the petals; in Hamamelis they are oblong fleshy bodies, alternating with the fertile stamens; in Pentapetes they are filiform, and placed between every three fertile stamens; in Zingiberaceæ they are minute gland-like corpuscles, a very common form (Plate IV. fig. 10. *c*); in Brodiæa they are bifid petaloid scales; and in Asclepiadaceæ they undergo yet more remarkable transformations. Dunal calls these sterile stamens *lepals* (*lepala*); a term which has not yet been adopted.

9. Of the Pollen.

The pollen is the pulverulent substance which fills the cells of the anther. It consists of extremely minute grains, varying in size, and enclosing a fluid containing molecular matter. The pollen-grains are often called *granules*.

To this important part of the organisation of perfect plants, attention has been directed with great care and skill by numerous observers of the first class, among whom are especially to be noticed R. Brown, Ad. Brongniart, Fritzsche, Griffith, Mirbel, Mohl, and Schleiden. From their enquiries, we have arrived at a knowledge of the history of the pollen, notwithstanding its minuteness, from its first secretion to its final destruction, after the important purpose for which it is provided has been attained.

The *origin of the pollen*, according to the testimony of all observers, occurs in the cells of which the anther is composed, and appears to consist in a peculiar organisation of their granular interior. The grains are usually produced in fours, by the bisection of their generating cell in two opposite directions, but are occasionally formed in pairs or singly.

In 1831, Brown speaks thus of the evolution of the pollen of Tradescantia virginica. "In the very early stage of the flower bud, while the antheræ are yet colourless, their loculi are filled with minute lenticular grains, having a transparent flat limb, with a slightly convex and minutely granular semi-opake disk. This disk is the nucleus of the cell, which probably loses its membrane or limb, and, gradually enlarging, forms in the next stage a grain also lenticular, and which is marked either with only one transparent line, dividing it into two equal parts, or with two lines crossing at right angles, and dividing it into four equal parts. In each of the quadrants a small nucleus is visible: and even where one transparent line only is distinguishable, two nuclei may often be found in each semicircular division. These nuclei may be readily extracted from the containing grain by pressure, and, after separation, retain their original form. In the next stage examined, the greater number of grains consisted of the semicircular divisions already noticed, which had naturally separated, and now contained only one nucleus, which had greatly increased in size. In the succeeding state the grain apparently consisted of the nucleus of the former stage, considerably enlarged, having a regular oval form, a somewhat granular surface, and originally a small nucleus. This oval grain continuing to increase in size, and in the thickness and opacity of its membrane, acquires a pale yellow colour, and is now the perfect grain of pollen." (*On Orchid. and Asclep.* p. 21.)

In 1832, Mirbel examined the developement of pollen in the anther of a Gourd. He states that "when the flower-bud of this plant is about a line in length, each lobe of the anther is entirely composed of cellular tissue, the bladders of which present in general a pentagonal or hexagonal figure more or less regular when cut across. In every cell, without excepting even those which constitute the superficial layer of the lobe, are certain loose particles, of such extreme minuteness that a magnifying power of 500 or 600 diameters is required to examine them satisfactorily. I cannot compare them to anything better than to little transparent bladders, nearly colourless, more or less rounded, and of an equal size. I examined the cells of the lobe of the anther one by one; and I affirm that, at this early period, there is no trace of either the cells of the anther or of the grains of pollen. The whole of the tissue is perfectly uniform. In a flower-bud, but little larger than the first, I remarked on each side of the medial line of the slice a group, consisting of a few bladders, which were rather larger than the others, but otherwise like them. These larger bladders I propose to call *pollen-cells*, seeing that it is in their inside that the pollen is organised. In flower-buds, from 1½ to 2 lines in length, some remarkable changes were observable. The pollen-cells had become larger; their granules were so much multiplied that they were grouped and packed in opaque masses, and wholly filled the cells. These cells and granules together constituted a greyish body, joined to the rest of the tissue by the intervention of a cellular membrane, — a sort of integument which, notwithstanding its organic continuity with the surrounding parts, was readily distinguishable; for while the bladders of the surrounding parts lengthened parallel to the plane of the surface, and to the plane of the base of the anther, those of the integument lengthened from the centre to the circumference. In anthers a little further advanced, the sides of the pollen-cells, instead of being thin and dry as they had previously been, acquired a notable thickness, and their substance, gorged with fluid, resembled a colourless jelly. The cellular integument continued to adhere by its outer face to the lining of the cell of the anther, and by its inner face to the tissue formed by the pollen-cells. Three and a half or four lines of length in the flower-bud corresponded with a phenomenon altogether unexpected. At first the thick and succulent wall of each pollen-cell dilated, so as to leave a void between its inner face and the granules, not one of which separated from the mass, which proved that a force of some kind held them together. Shortly after four appendages, like knife blades, developed at equal distances on the inner face of the pollen-cell, and gradually directed their edge towards the centre, so that they began by cleaving the granular mass in four different lines, and finished by dividing it into four little triangular masses; and when the appendages met in the centre they grew together, and divided the cavity of the pollen-cell into four distinct cavities, which soon after rounded off their angles, and in a short time the little granular masses became spherical, like melted lead run into the hollow of a bullet-mould. The partition of the mass thus brought about by the appendages seems to me to indicate that at this period the mass was not protected by a special integument, and that the mutual adhesion of the granules was very weak.

"When things had arrived at this point, the portion of the tissue formed by the pollen-cells separated itself from the surrounding parts, and each pollen-cell became loose, generally in the form of a square parallelopiped with rounded angles; each little mass of granules gained a smooth, colourless, transparent membrane, which was at first membranous, but afterwards became thick and succulent, and soon began to take on the characters peculiar to the pollen of the Gourd. The integument began to bristle with fine conical papillæ; several roundish lids were traced out here and there on its surface; it hardened, became opaque, assumed a yellow colour, ceased to grow, and attained its perfect maturity." Mirbel adds to this highly interesting statement, that he finds in the generality of plants that the mode of forming the pollen is much the same as in the Gourd.

Observations upon the same subject by Professor Mohl were published at Berne, in 1834. The principal points of novelty in regard to the developement of the pollen are, that, 1. The union of pollen-grains in fours is sometimes permanent, sometimes very temporary. 2. That the four are sometimes placed upon the same plane, sometimes in the same relation to each other as the four angles of a cube. 3. That the original number of cohering grains is in most species of Inga, Acacia, and Mimosa, from eight to sixteen. 4. That the external coat of the pollen-grain is not an uniform membrane, analogous to that of a simple cell, but an organ composed of numerous cells like the integument of an ovule, although it appears in some cases to be simply granular, and in others to be almost homogeneous. This last idea is sharply attacked by Mirbel (*Ann. Sc.*; n. s., IV. 1.), who insists upon the external skin of the pollen-grain being simple in all cases.

Mr. Griffith, in November 1836, published some curious observations upon this subject, the result of which is, that in Pardanthus chinensis the pollen is developed in the midst of a solid grumous semiopaque mass, forming at a very early stage the contents of one of the four cells of the anther; That subsequently the grumous mass becomes cellular, the cells having undergone some separation, and consisting of a hyaline membrane containing a smaller mass of granular molecular matter. Later still, each cell, which has acquired an orange colour, presents traces of division into four, often into three, very rarely into two portions, the division being more distinct towards the circumference of each cell, and the smaller masses being each enclosed in a proper cell, but without having undergone any separation. Eventually each of the divisions becomes a pollen-grain. "The young grains are oblong-ovate, flattened on their contiguous or inner faces, and open along the centre throughout the whole length of their outer faces. They are even at this period reticulated, and have rather a papillose appearance, and are lined by an inner membrane in the form of a hyaline sac, which bulges out slightly along the opening just mentioned."

According to Schleiden, the difference between ordinary pollen and that found in *masses* in Asclepiadaceæ and Orchidaceæ consists in this, that the enveloping cells in common cases *are*, and in the two others *are not*, absorbed. "This same condition may be seen as a temporary stage in the developement of Picea and Abies, in the months of January and February, in Pinus in February and March, in which a loose waxy pollen mass may be found embedded in each division of the anther. At a somewhat later period we may see the four cells in Picea and Abies, in which the four pollen-grains lie closely united; and it offers a pleasing spectacle under the microscope to observe each grain expand itself by the absorption of water until it bursts its case in order to escape, leaving the four cells emptied of their contents."

Link supposes the cellular substance in which pollen is generated to be semiorganic, and calls it *collenchyma*, considering with me that it is what forms the appendage of the pollen masses of Orchidaceæ. But it can hardly be called semiorganic, especially if it is examined in Polystachya ramulosa.

It also appears from Mr. Francis Bauer's observations, that the masses of pollen of both Asclepiadaceæ and Orchidaceæ, in the most solid state, are truly cellular, the grains of pollen being contained in cavities, the walls of which are either separable from each other, as in some Orchidaceæ, or are ruptured without a separation of the cavities, as in Asclepiadaceæ. (See the *Observations on Orchidaceæ and Asclepiadaceæ*, before referred to.) It does not however follow that because pollen is engendered in the interior of cells, its grains must therefore adhere originally by an umbilicus; and in fact the part so described by Turpin has no existence.

When they are fully formed the granules are generally discharged at once, upon the dehiscence of the anther. But in some Araceæ, which emit their pollen by a hole in the apex of their anther, the formation or developement of pollen must be going on for a considerable time after the first emission. A single anther continues to secrete and discharge pollen, till, as Brown remarks, the whole quantity produced greatly exceeds the size of the secreting organ.

The *surface* of the pollen is commonly smooth. In some plants it is hispid, as in the Gourd and Ipomœa purpurea;

in others it is covered with strong points, as Hibiscus syriacus; in Jatropha panduræfolia it is granular; in many Labiatæ, banded; in Passiflora, reticulated; in Geranium sylvaticum, crested; in Armeria vulgaris, polygonal, with crested angles, among which are some of the most beautiful microscopical appearances in the vegetable kingdom. In all cases, where there are asperities of the surface or angles in the outline, pollen is asserted by Guillemin to have a mucous surface, which was first observed in Proteaceæ by Brown. But Mohl finds that the presence of mucosity upon pollen is a constant character, at least when the grains first quit the anther; and that a power of secreting a viscid substance is one of their functions when perfectly smooth, as well as when covered with points and inequalities. He, however, admits that hispid pollen is generally more viscid than that which is smooth.

The *figure* of the granules is various; most frequently it is spherical or slightly oblong. Many other forms have, however, been described. The cylindrical exists in Anethum segetum, and in a very remarkable degree in Tradescantia virginica, where the grains become curved: in Colutea arborescens, they were observed by Guillemin to be nearly square; in Lavatera acerifolia to be oval, much attenuated to each end; in Œnothera they are triangular, with the angles so much dilated as to give the sides a curved form; in Jacaranda tomentosa I have remarked them to be spherical, with three projecting ribs tapering to either apex; in Cichoraceæ the granules are spherical with facettes; in Dipsaceæ a depressed polyedron; in Scabiosa caucasica, patelliform and angular. In numerous plants it is oval, with a furrow on one side, like a grain of wheat; in Thunbergia fragrans, Mimulus moschatus, &c., it is strongly ribbed, as if formed of many folds; in Morina persica, cylindrical, with a narrow neck rising abruptly from each side; in Scolymus, Scorzonera, &c., it is a polygon, with crested angles; and of all these there are numerous modifications, some of which are represented in Plate IV.

In consequence of the great diversity of forms observable in pollen, it has been supposed that it might be employed in the definitions required for systematic botany; and Messrs. Guillemin and Adolphe Brongniart have stated that plants of the same family have similar pollen, adducing as instances Graminaceæ, Cyperaceæ, Thymelaceæ, Proteaceæ, &c., &c. But Mohl, who has inquired into this part of the subject in a most elaborate manner, declares that pollen varies extremely in form, not only in genera of the same family, but also in species of the same genus; and that it even occurs in some plants that the same anther contains grains, "de formation assez diverse." The more or less complex structure of the pollen is not in relation to the more or less elevated station of a plant in the scale of developement; but the same form is found in families so different, that they are separated by every other point of structure.

The *shell of the pollen-grain* appears to the observer who examines it with low magnifying powers, as if it were simple. But it has been ascertained to consist in the greater part of plants of two or even three membranes, of which the outer (*extine*) is thicker than the inner (*intine*), the latter being hyaline, extensible, and of extreme tenuity, not colourable by iodine, and destructible by concentrated sulphuric acid. Mohl considers the extine to be in all cases composed of minute grains, or cells, held together by organic mucus: that it is often cellular there is no doubt; he refers, in proof of the correctness of this opinion, to cases where, as in Pitcairnia latifolia, the coating is manifestly cellular in the middle of the pollen-grain, but becomes granular at the extremities. He also states, that in other cases the points forming granulations become less and less, till, at last, the membrane becomes almost entirely smooth and uniform, and is extremely like the membrane in the common cells of plants; as in Allium fistulosum, Araucaria imbricata, &c. Mirbel, however, disputes the cellularity of the extine; and Fritzsche, in his latest work, asserts that it unquestionably is sometimes a simple membrane (p. 30.). The intine has the power of absorbing water with great force, so that immediately upon being exposed to the action of a fluid it swells, and eventually bursts, discharging its contents; in general the extine extends as well as the intine, and then the organic difference between them is not observable: but in Taxus, Juniperus, Cupressus, Thuja, the outer membrane has, as Mohl states, so little extensibility, that it is torn irregularly, and the inner membrane protrudes beyond the crevices, and, swelling more and more, generally disengages itself from the extine. It sometimes happens that the inner membrane protrudes beyond the outer shell, in the form of a short sac or tube: this phenomenon may be produced artificially at will by placing the pollen-grain in weak nitric or sulphuric acid; but it is quite a distinct emission from that of the pollen-tubes hereafter to be noticed.

A third membrane, intermediate between the extine and intine, was first noticed by Mohl in the pollen of Taxus, Juniperus, Cupressus, and Thuja. Fritzsche calls it the *Exintine*, and finds it not only in these plants, but also in Pinus, Cucurbita Pepo, and Tigridia Pavonia, and considers it probably a common structure. The same minute observer speaks of four coatings to the pollen of Clarkia elegans, calling the fourth, which is next the extine, the *Intexine;* he also finds the same structure in other Onagraceæ.

Mohl names Asclepiadaceous plants as those only in which pollen has but one tunic; but Fritzsche asserts that these plants have both an extine and intine, and he figures them in Asclepias syriaca; he adds, that in Caulinia fragilis, Zannichellia pedunculata, Zostera marina, and Naias minor, the pollen has really nothing but the intine present.

There are few forms of pollen in which the extine presents the appearance of a vesicle completely closed. In many cases the grains are marked by a longitudinal furrow on one side, and look when dry like a grain of wheat. Mr. Griffith has shown, as is above stated, that this appearance is caused by a fissure in the extine, and if such pollen is put into water the fissure becomes less visible. The presence of one or more such clefts is of common occurrence; and have been supposed to be openings through the extine down to the intine; Mohl, however, considers them not to be really openings, but only extremely thin spaces in the extine. Fritzsche calls them pores, and regards them as certainly openings. Instead of slits many kinds of pollen have circular holes, varying in number, in different species, from one to an indefinite quantity in Alcea rosea. Under these holes Fritzsche finds small, plano-convex, lenticular bodies (*zwischenkörpern*), lying between the extine and the intine, with their convexity reposing upon the latter; he represents them as particularly visible and large in some Malvaceæ.

The *colour* of pollen is chiefly yellow. In Epilobium angustifolium and many Polemoniaceæ it is blue; in Verbascum it is red; and it occasionally assumes almost every other colour, except green. According to Fourcroy and Vauquelin, the pollen of the Date tree consists of malic acid, phosphate of magnesia and lime, and also of an insoluble animal matter intermediate between gluten and albumen. Macaire Prinsep has ascertained that the pollen of the Cedar contains malate of potass, sulphate of potass, phosphate of lime, silica, sugar, gum, yellow resin, and a substance which, by its characters, approximated to starch. Being analysed as a whole, it gave, per cent., 40 carbon, 11·7 hydrogen, and 48·3 oxygen, but no nitrogen. — *Bibl. Univers.* 1830. 45.

The matter contained in the granules is called the *fovilla*. Under common magnifiers it appears like a turbid fluid; under glasses of greater power it has been found to consist of a multitude of particles moving on their axes with activity, of such excessive minuteness as to be invisible unless viewed with a magnifying power equal to 300 diameters, and measuring from the 4000th or 5000th to the 20,000th or 30,000th of an inch in length. This motion was first distinctly noticed by Gleichen; but it seems to have escaped the recollection of succeeding botanists until the fact was confirmed by Amici, who some time before 1824 saw and described a distinct, active, molecular motion in the pollen of Portulaca oleracea. In 1825 the existence of this motion was confirmed by Guillemin, who ascertained its presence in other species. In June 1827, I was shown the motion by Dr. Brown, who subsequently published some valuable observations upon the subject, without, however, noticing those of either Amici or Guillemin. The most important addition that was made by Brown to the knowledge that previously existed, consisted in the discovery of the presence of two kinds of active particles in pollen; of which, one is spheroidal, extremely minute, and not distinguishable from the moving, ultimate, organic molecules common to all parts of a vegetable; the other, much larger, often oblong, and unlike any other kind of particle hitherto detected in plants. Clarkia pulchella, and some other Onagraceous plants, show this difference, as well as the motion, in a very conspicuous manner. In consequence of their manifest motion it has been conjectured that the larger particles of the fovilla were the incipients of the embryo, and that it is by the introduction of one or more of these into the ovule that the act of impregnation is accomplished by the deposit of a rudimentary embryo in the ovule. But both Fritzsche and Mohl agree in considering many of the smaller particles of the fovilla as minute drops of oil: the molecular motion has been ascribed to currents in the fluid, in which the fovilla is suspended, and which, according to Fraunhofer, no precautions can possibly prevent; and, what is more important, the larger particles become blue upon the application of iodine, without however losing their property of motion, as Fritzsche has shown: they are therefore starch.

When the pollen falls upon the stigma it emits a fine transparent tube, which is a prolongation of the intine, and down which the fovilla passes until the grain is emptied. The *pollen-tube* thus formed was first observed by Amici, and is now known to be constantly produced at the period of impregnation. Of the important offices these tubes have to perform an account will be given in Book II. Chap. vi.

For further information concerning pollen the reader is referred to the following works: —

1. Fritzsche, *De Plantarum Polline:* Berolini, 1833. This ingenious observer found that several modes of examining pollen are preferable to those usually employed: in particular he recommends the employment of sulphuric acid, in the proportion of two parts of concentrated acid to three parts of water, for the purpose of viewing the pollen by transmitted light; by this means it is rendered transparent, and the spontaneous emission of pollen-tubes is effected. In cases of very opaque pollen he employs oil instead of diluted acid, and he finds it renders an object more transparent than the acid itself; and in other cases, where the coat of the

pollen is either too much or too little transparent to show the apertures in its sides, he finds a solution of iodine in weak spirits of wine extremely useful.—2. Mohl, *Sur la Structure et les Formes des Grains de Pollen* : translated from the German in the *Annales des Sciences*, n. s., III. 148.—And, 3., to Fritzsche, *Ueber der Pollen* : 4to, St. Petersburgh, 1837, with thirteen coloured plates. In this last excellent work all the refinements of optical instruments and chemical manipulation have been employed in the investigation of the subject.

10. Of the Disk.

By this term are meant certain bodies or projections, situated between the base of the stamens and the base of the ovary, but forming part with neither; they are referred by the school of Linnæus, along with other things, to nectarium: Link calls them *sarcoma* and *perigynium* ; and Turpin, *phycostemones*. The most common form is that of a fleshy ring, either entire or variously lobed, surrounding the base of the ovary (Plate V. fig. 4. *e*, 8. *d.*) as in Lamium, Cobæa, Gratiola, Orobanche, &c.; in Gesneraceæ and Proteaceæ the disk consists of fleshy bodies of a conical figure, which are usually called *glandulæ hypogynæ*. It occasionally assumes the appearance of a cup, named by De Candolle, in Pæonias and Aconites, *lepisma*, a bad term, for which it is better to say *discus cyathiformis*. In flowers with an inferior ovary (Plate V. fig. 9. *c*, 7. *c*) the disk necessarily ceases to be hypogynous, and generally also to appear in the form of scales. In Compositæ it is a fleshy solid body, interposed between the top of the ovary and the base of the style; and has given rise, when much enlarged, to the unfounded belief in the existence of a superior ovary in that order, as in Tarchonanthus. In Apiaceæ it is dilated, and covers the whole summit of the ovary, adhering firmly to the base of the styles; by Hoffmann it is then called *stylopodium*, a word which is seldom used.

It is an opinion which daily gains ground, that the disk is really only a rudimentary state of the stamens; and it is thought that proofs of the correctness of this hypothesis are to be found in the frequent separation of the cyathiform disk into bodies alternating with the true stamens, as in Gesnera; in its resemblance in Parnassia to bundles of polyadelphous stamens; and particularly in the fact noticed by Brown, that an anther is occasionally produced upon the highly developed disk of Pæonia Moutan. To which may be added the observation of Dunal, that half the disk of Cistus vaginatus occasionally turns into stamens. (*Considerations*, &c., p. 44.)

Like the petals, sepals, and stamens, the disk always originates below the pistil; but it often contracts an adhesion with the sides of the calyx, when it becomes *perigynous*, as in Amygdalus; or with both the calyx and the sides of an inferior ovary, when it becomes *epigynous*, as in umbelliferous plants.

11. Of the Pistil.

The last organ to enumerate in the flower is that which constitutes the *female system*, or *gynæceum* of Röper, and which is usually called the *pistil*. In all cases it occupies the centre of the flower, terminating the axis of growth of the peduncle: and is consequently the part around which every other organ, without exception, is arranged.

It is distinguished into three parts; viz. the *ovary* (Plate V. fig. 7. *a*), the *style* (fig. 7. *f*), and the *stigma* (fig. 7. *g*).

The ovary, called germen by Linnæus, is a hollow case placed at the base of the pistil, enclosing the *ovules*, and always containing one or more *cells* or cavities. It is the part which ultimately becomes the fruit; and consequently, whatever may be the structure of the ovary, such must necessarily be that of the fruit: allowance being made, as will hereafter be explained, for changes that may occur during the progress of the ovary to maturity.

Notwithstanding what has been stated of the pistil constantly occupying the centre of the flower, and being the part *around* which all the other parts are arranged, an apparent exception exists in those flowers the calyx of which is said to be superior (Plate V. fig. 7. & 9.), as the Apple blossom. In this instance, the ovary seems to originate *below* the calyx, corolla, and male system; on which account it is said to be *inferior* in such cases, while in the opposite state it is called *superior*. But, in reality, the inferior ovary is only so in consequence of the tube of the calyx *contracting an adhesion with its sides*; and such being the case, the exactness of the description of the constant place of the pistillum as above is unshaken. This is proved in many ways. In Saxifragaceæ, the genus Leiogyne has the ovary superior; in Saxifraga itself the calyx partially adheres to the sides of the ovary, which then becomes half inferior; while in Chrysosplenium the union between the calyx and ovary is complete, and the latter is wholly inferior. Again, in Pomaceæ, the ovaries partially cohere with the calyx in Photinia, completely in Pyrus, and by their backs only in Cotoneaster; whence the ovary is half superior in the first instance, quite inferior in the second, and what is called *parietal* in the third. (Botanists call any thing *parietal* which arises from the inner lining or wall of an organ; thus in Cotoneaster the ovaries are parietal, because they adhere to the inner lining of the calyx, and in Papaver the placentæ are parietal because they originate in the inner lining of the fruit.)

Sometimes the ovary, instead of being sessile, as is usually the case, is seated upon a long stalk; as in the Passion flower and the genus Cleome. This stalk is often called the *thecaphore* or *gynophore* (also *basigynium* or *podogynium*); but it is obviously analogous either to the petiole of a leaf, or to an internodium, and the application of a special term to it appears unnecessary. Cassini calls the elongated apex of the ovary of some Compositæ *le plateau.*

That part of the ovary from which the ovules arise is called the *placenta* (*trophospermium*, Richard; *spermaphorum*, *colum*, *receptacle of the seeds*). It generally occupies the whole or a portion of one angle of each cell (Plate V. fig. 1. *e*, 2. *c*, &c.), and will be spoken of more particularly hereafter. It is sometimes elongated in the form of a little cord, as in the Hazel nut, and many Brassicaceæ: it is then called the *umbilical cord* (*funiculus umbilicalis*, *podospermium*).

The swelling of the ovary after fertilisation is termed *grossification*.

The *style* (*tuba* of old authors) is that elongation of the ovary which supports the stigma (Plate V. fig. 7. *f*). It is frequently absent, and then the stigma is sessile: it is not more essential to a pistil than the stalk to a leaf, or the claw to a petal, or the filament to a stamen. Anatomically considered, it consists of a column of one or more bundles of vascular tissue, surrounded by cellular tissue; the former communicating on the one hand with the stigma, and on the other with the vascular tissue of the ovary. It is usually taper, often filiform, sometimes very thick, and occasionally angular: rarely thin, flat, and coloured, as in Iris and in Canna. In some plants it is continuous with the ovary, the one passing insensibly into the other, as in Digitalis; in others it is articulated with the ovary, and falls off, by a clean scar, immediately after fertilisation has been accomplished, as in the Scirpus. Its usual point of origin is from the apex of the ovary; nevertheless, cases occur in which it proceeds from the side, as in Alchemilla, or even from the base, as in Labiatæ and Boraginaceæ. In these cases, however, it is to be understood that the geometrical and organic apices are different, the latter being determined by the origin of the style. For this reason, when the style is said to proceed from the side or base of the ovary, it would be more correct to say that the ovary is obliquely inflated or dilated, or that it is gibbous at the base of the style.

The surface of the style is commonly smooth; but in Compositæ, Campanulaceæ, and others, it is often densely covered with hairs, called *collectors*, which seem intended as brushes to clear the pollen out of the cells of the anthers. In Lobelia these hairs are collected in a whorl below the stigma; in Goodeniaceæ they are united into a cup, in which the stigma is enclosed, and which is called the *indusium* (Plate V. fig. 13. *b*). Many styles which appear to be perfectly simple, as for instance those of the Primrose, the Lamium, the Lily, or the Borage, are in reality composed of several grown together; as is indicated by the lobes of their stigma, or by the number of cells or divisions of their ovary. In Malva an example may be seen of a partial union only of the styles, which are distinct upwards, but united below. In speaking of styles in this latter state, botanists are accustomed to describe them as *divided* in different ways, which is manifestly an inaccurate mode of expression.

The *stigma* is the upper extremity of the style, without epidermis; in consequence of which it has, almost uniformly, either a humid or papillose surface. In the first case it is so in consequence of the fluids of the style being allowed to flow up through the intercellular passages of the tissue, there being no cuticle to repress and conceal them; in the latter case the papillæ are really the rounded sides of vesicles of cellular tissue. When perfectly simple, it is usually notched on one side, the notch corresponding with the side from which the placenta arises: see the stigma of Rosa, Prunus, Pyrus, and others. If it belongs to a single carpel, it is either undivided, or its divisions, if any, are placed side by side, as in Euphorbiaceæ, Crocus, &c.; but if it is formed by the union of the stigmas of several carpels, its lobes are either opposite each other, as in Mimulus, or placed in a whorl, as in Geranium. Such being the case, it is a general law that an apparently simple ovary, to which more than two opposite stigmas belong, is really of a compound nature; but, when the stigma of a simple carpel is two-lobed, the arms are often placed exactly opposite each other, as in Compositæ, Graminaceæ, &c., and then the apparent number of the stigmas is not the real number.

Nothing is, properly speaking, stigma, except the secreting surface of the style; it very often, however, happens, that the term is carelessly applied to other portions of the style. For example, in the genus Iris, the three petaloid lobed styles in the centre are called stigmata; while the stigma is in reality confined to a narrow humid space at the back of each style: in Labiatæ, Bentham has shown that what is called a two-lobed stigma has a two-lobed style, the points only of the lobes of which are stigmatic: and in Lathyrus, and many other papilionaceous plants, Linnæan botanists call the hairy back of the style the stigma; while, in fact, the latter is confined to the mere point of the style.

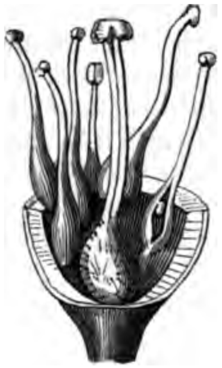
Nevertheless, there are certain stigmas in which no denuded or secreting surface can be detected. Of this nature is that of Tupistra, in which the apparent stigma is a fungous mass with a surface of the same nature as that of the style; in such a stigma the mode of fertilisation forms an interesting problem, which botanists have yet to solve.

The centre of a stigma consists of tissue of a peculiar character, which communicates directly with the placenta, and which is called the *conducting tissue.* It is more lax than that which surrounds it, and serves for the conveyance of the fertilising matter of the pollen into the ovules. Schleiden well observes that, as a style is a portion of a leaf rolled up, or formed by a union of the edges of many leaves (as will be presently shown), the centre of the style must answer to the epidermis of the upper side of such leaf, and therefore this epidermis, modified, constitutes the *conducting tissue.* If the convolution or approximation of the carpels is very complete, the tissue will be a mere thread; but if it be imperfect, as in Orchidaceæ, &c., the tissue will form the lining of a funnel-shaped passage from the stigma to the cavity of the ovary.

Such is a general view of the more remarkable peculiarities of the female system. This part, however, bears so important an office in the functions of vegetation, is so valuable as a means of scientific arrangement, and is liable to such a great variety of modifications, that it will be necessary now to regard it in another and more philosophical point of view. For we have yet to consider the structure of the compound pistil, and to learn to understand the exact nature of its cells, and dissepiments, and placentæ, and the precise relation that these parts bear to each other; and also to prove that the necessary consequence of the laws under which pistils are constructed is, that they can be subject to only a particular course of modification, within which every form must absolutely, and without exception, fall. This enquiry would, perhaps, be less important, if none but structure of a very regular and uniform kind were to exist; but, considering the numberless anomalies that the pistil exhibits, it becomes at once one of the most difficult and most essential parts of a student's investigation.

In the days of Linnæus and Gærtner, and even in those of the celebrated L. C. Richard, nothing whatever was known of this matter, and consequently the writings of those carpologists are a tissue of ingenious misconceptions. Nor did the subject become at all intelligible, notwithstanding the writings of Wolff, until the admirable treatise upon Vegetable Metamorphosis, which had been published by Goethe in 1790, but which had long been neglected, was again brought into notice, and illustrated by the skilful demonstrations of De Candolle, Turpin, Du Petit Thouars, and others.

121



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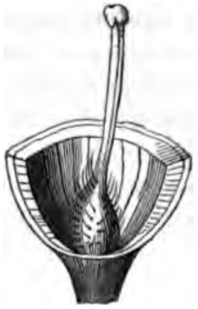


According to these writers, the pistil is either the modification of a single leaf (*fig.* 122.), or of one or more whorls of such leaves (*fig.* 121.), which are technically called *carpels.* Each carpel has its own ovary, style, and stigma, and is formed by a folded leaf, the upper surface of which is turned inwards, the lower outwards, and the two margins of which develope one or a greater number of buds, which are in a rudimentary state, and are called the ovules.

A clear idea of the manner in which this occurs may be obtained from the carpel of a double cherry, in which the pistil loses its normal carpellary character, and reverts to the structure of the leaf. In this plant the pistil is a little contracted leaf, the sides of which are pressed face to face, the midrib elongated, and its apex discoloured, or a little distended. If we compare this with the pistil of a single cherry, the margins of the leaf with the ventral suture, the elongated midrib with the style, the discoloured distended apex with the stigma, they will be found to correspond exactly.

In this case there is an indisputable identity of origin and nature between the ovary and the blade of a leaf; between the little suture that occupies one angle of the carpel of a cherry, and the line of union of the two edges of the leaf; and between the elongated midrib, with its distended apex, and the style and stigma. There can be no doubt that the plan of all carpels is the same; so that the ovary is the blade of a leaf, the style an elongated midrib, and the stigma the denuded, secreting, humid apex of the latter.

Such being the origin of the carpel, its two edges will correspond, one to the midrib, the other to the united margins of the leaf. These edges often appear in the carpel like two sutures, of which that which corresponds to the midrib is called the *dorsal*, that which corresponds to the united margins is named the *ventral*, *suture*.

It is at some part of the ventral suture that is formed the *placenta*, which is a copious developement of cellular substance, out of which the ovules or young seeds arise. It, the placenta, originates in both margins of the carpellary leaf: but, as they are generally in a state of cohesion, there appears to be but one placenta; nevertheless, if, as sometimes happens, the margins of the carpellary leaf do not unite, there will be two obvious placentæ to each carpel. Now, as the stigma is the termination of the dorsal suture, it occupies the same position as that suture with regard to the two placentæ; consequently the normal position of the two placentæ of a single carpel will, if they are separate, be right and left of the stigma. This is a fact important to bear in mind.

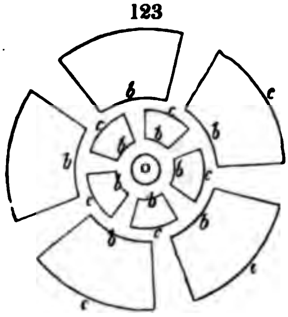
Pistils consisting of but one carpel are simple; of several, are compound. If the carpels of a compound pistil are distinct entirely or in part, they are *apocarpous*, as in Caltha; if they are completely united into an undivided body, as in Pyrus, they are *syncarpous*. That syncarpous pistils are really made up of a number of united carpels is easily shown, as

Goethe has well remarked, in the genus Nigella, in which N. orientalis has the carpels partially united, while N. damascena has them completely so; in the latter case, however, the styles are distinct. They and the stigmas are all consolidated in a single body, when the pistil acquires its most complete state of complication, as in the Tulip; which is, however, if carefully examined, nothing but an obvious modification of such a pistil as that of Nigella damascena.

This important conclusion is deducible from the foregoing considerations: viz., that, as the carpels are modified leaves, they are necessarily subject to the same laws of arrangement, *and to no others*, as leaves developed around a common axis upon one or several planes. For no axiom appears more incontestable in botany, than that all modifications of a given organ are controlled essentially in the same way, and by the same influences, as the organ itself in an unmodified state: and hence every theory of the structure of fruit which is not reducible to that which would be applicable to the structure of whorls of leaves is vicious of necessity. I shall proceed to demonstrate the perfect accordance of the carpellary theory of structure in every point with these principles.

The placenta usually arises from the two margins, either distinct or combined, of a leaf folded inwards. When a leaf is folded inwards, its margins will point towards the stem or axis around which it is developed; and in a whorl of leaves such inflected margins would all be collected round a common centre; or, if the axis were imaginary, in consequence of the whorl being terminal, would be placed next each other, in a circle of which the back of the leaves would represent the circumference. Therefore the placentæ will always be turned towards the axis, or will actually meet there, forming a common centre; and, which is a very important consequence of this law, if one carpel only, with its single placenta, be formed in a flower, the true centre of that flower will be indicated by the side of the carpel occupied by the placenta. Proofs of this may be found in every blossom: but particularly in such as, habitually having but one carpel, occasionally form two, as the Wistaria sinensis, Alchemilla arvensis, Cerasus acida, &c.; in these the second carpel, when added, does not arise by the side of the first, but opposite to it, the face of its placenta being in front of that of the habitual carpel. A fourth proof of this uniform direction of the placentæ towards the axis is afforded by those pistils in which a great number of carpels is developed in several rows, as in the Strawberry and the Ranunculus: in all these the placentæ will be, without exception, found directed towards the axis, and consequently towards the back of every row, except the inner. For example, in the following diagram (123.), let o be the axis, *b b* placentæ, *c c* the backs of carpels; the placentæ, *b b*, of the inner row will be next the centre o; the placentæ, *b b*, of the second row will be next the backs, *c c*, of the first row; and so on.

123



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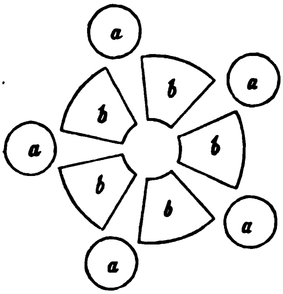
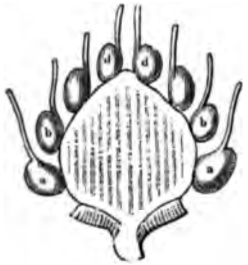


If the order of developement of leaves were exactly followed in that of the stamens and carpels, it would happen that the latter would be invariably alternate with the inner row of stamens; for, if *a a* (*fig.* 124.) are the stations of five stamens, *b b* would be the situations of the carpels: this relative position is therefore considered the normal one, and is in fact that which usually exists in perfectly regular flowers; but as all the parts of a flower, in consequence of the non-developement of some parts, or the excessive developement of others, are subject to deviations, either real or apparent, from what is considered their normal state, it frequently happens that the carpels either bear no apparent relation to the stamens or are opposite to them. In papilionaceous plants, for example, where only one carpel is present, it is difficult to say that it bears any exact relation to the stamens, although it is probable that its position is really normal with regard to them; and so also in rosaceous plants, with numerous carpels, no exact relation can be proved to exist between the latter and the stamens, unless it may be said to be indicated by those genera, such as Spiræa, in which the carpels are reduced to five; and, finally, in such plants as Delphinium, in which the carpels are three, while the floral envelopes and male system are divided upon a quinary plan, it is manifest that no alternation can exist between the stamens and carpels.

As the sepals and petals most commonly consist each of a single whorl of parts, so the pistil is more frequently composed of one whorl of carpels than of more. There are, however, certain families in which several whorls are produced one within the other, as in Fragaria, Ranunculus, Magnolia, Anona, and the like. In these cases it mostly happens that the carpels are either entirely separate or nearly so; but it sometimes is found that syncarpous pistils are habitually produced with more than one whorl of carpels, and consequently of cells, as Nicotiana multivalvis, and some varieties of the genus Citrus. In such instances the placentæ of the outer series will necessarily be applied to the backs of the inner series, as has been just demonstrated.

This mutual relation of the different rows of carpels is sometimes observed when the receptacle from which they arise is either convex or concave: in the former state the outer series will obviously be lowermost, and in the latter uppermost; a circumstance that leads to no intricacy of structure when the carpels are distinct, but which may cause an exceedingly anomalous structure in syncarpous pistils, especially when accompanied by other unusual modifications.

125



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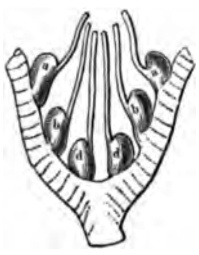

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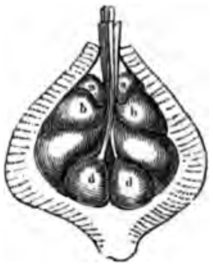


There can be no doubt that the true nature of the composition of the pomegranate is to be explained upon this principle. In order to make these considerations more clear, let *figs.* 125, 126, and 127. represent—*fig.* 125. a convex receptacle, with distinct carpels; *fig.* 126. a concave one, with the same; and *fig.* 127. a concave one, with the carpels consolidated. In these, *a a* are the outer row of carpels, *b b* the next, and *d d* the central row. The relative position of these, as the receptacle is convex or concave, will now be apparent.

I have stated that the placenta, however simple it may appear to be, is usually produced by the union of two united margins of a carpellary leaf: it is, therefore, essentially double; and, accordingly, we find that in polyspermous ovaries the ovules are almost always arranged in two rows, as in the Pea and Bean, the Quince, the Pæony, &c.

But there are exceptions to this rule. In *Taylor's Magazine* for Nov. 1837, I have shown that in Orobanchaceæ the placentæ undoubtedly arise from the face of the carpel. That their capsule consists of two carpels standing right and left of the axis of inflorescence, and with the margins not inflected in the form of dissepiments, is incontestable. Yet in Orobanche and Phelypæa the capsule has the placentæ placed equidistant in pairs upon the face of each valve or carpel, and considerably within the margin. In Epiphegus each carpel has two intramarginal placentæ, which diverge from the base upwards, and terminate before reaching the apex. In Lathræa there is to each valve but one placenta, which may be regarded as two confluent ones occupying the very face of the dorsal suture of the carpel. And finally in Æginetia indica, and I believe in Æginetia abbreviata also, the placenta is in like manner confined to the axis of the valve, occupying the same position upon the carpels as in Lathræa, but broken up into a number of parallel plates of unequal depth, over the whole surface of which multitudes of minute seeds are distributed. If we connect these facts, about which there can be no sort of question, with the well known placentation of Flacourtiaceæ, Nymphæaceæ, and Butomaceæ, we shall find that they invalidate the general carpological rule, that the placentæ belong to the ventral suture of a carpel, and consequently alternate with the dorsal; and we shall have to admit that the position of the placentæ with regard to the margins of the carpel is reducible to no certain rule, but depends upon specific organization. Consequently we shall no longer be unable to account for the unusual situation of the placentæ opposite the stigma, in Papaver (as M. Kunth has lately noticed), in Parnassia, or elsewhere.

We ought not indeed to be surprised at coming to this result; for if the ovules are, as botanists generally believe them to be, a modification of buds, then the uncertainty in the position of the placentary lines will only be conformable to the uncertainty in the origin of buds from leaves. If in Bryophyllum, Malaxis paludosa, and most other cases, they usually spring from the edge of the leaf, they also arise from its surface in ferns; and in the famous case of the Ornithogalum leaf mentioned by Turpin, they were found issuing indiscriminately from all parts of its face.

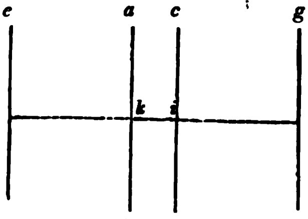
When two leaves are developed upon a stem, they are always opposite, and never side by side. As carpels are modified leaves, they necessarily obey this law; and, consequently, when a pair of carpels forms a bilocular ovarium, the separation of the two cells is directly across the axis of the flower.

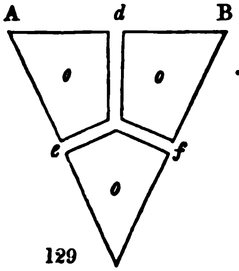
The partitions in ovaries, that are formed by the united sides of cohering carpels, and which separate the inside into cells, are called *dissepiments* or *septa*. It is important to bear in mind, not only that such is really their origin, but that they cannot possibly have any other origin, in order to form an exact idea of the structure of pistils. Now, as each dissepiment is thus formed of two united sides, it necessarily consists of two plates, which are, in the ovary state, often so completely united, that their double origin is undiscoverable, but which frequently separate in the ripe pericarp. This happens in Rhododendron, Euphorbia, Pentstemon, and a multitude of other plants. The consideration of this circumstance leads to certain laws which cannot be subject to exception, but which are of great importance; the principal of which are these: —

1. *All dissepiments are vertical and never horizontal.* — For if *a b*, in *fig.* 128., represents the side of one carpel, and *c d*, that

of another, the dissepiment *a c b d*, formed by this union, will have precisely the same direction as that of the carpels, and can never acquire any other; and the same would be true of the sides *e f* and *g h*, if they formed themselves into dissepiments by uniting with other carpels: consequently a partition in any cell in the direction of *i k* could not be a dissepiment, but would be of a different nature.

128



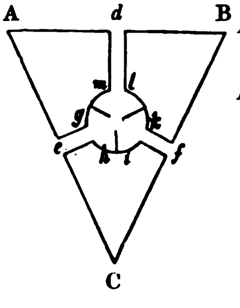


129

2. *They are uniformly equal in number to the carpels out of which the pistillum is formed.*—Suppose the triangle A B C represented a transverse section of an ovary formed by the union of three carpels *o*, *o*, *o*; then *d*, *e*, *f* would be the dissepiments, and could not be either more or less in number.

3. *They proceed directly from the placenta, when that part originates in the margin of the carpel.*—As the placenta is the margin of the carpellary leaf, and as the dissepiment is the side of the carpellary leaf, it is evident that in such a case a dissepiment cannot exist apart from the placenta. Hence, when any partition exists in an ovary and is not connected with the placenta, if marginal, it follows that such a partition is not a dissepiment, however much it may otherwise resemble one.

130



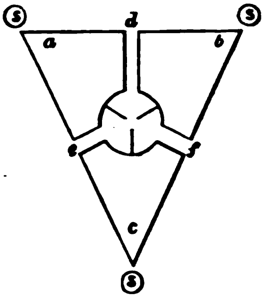
4. *They are alternate with placentæ formed by the cohesion of the margins of the same carpel, and opposite to placentæ formed by the cohesion of the contiguous margins of different carpels.*—Let the triangle A B C represent a transverse section of a three-celled ovary of which *d*, *e*, *f* are the dissepiments: the dissepiments *d* and *e* will alternate with the placentæ *m*, *g*, both belonging to the carpel A; but the dissepiment *d* will be opposite the placentæ

m, *l*, formed by the cohesion of the contiguous margins of the carpels A and B.

5. *A single carpel can have no true dissepiment.*

6. *The dissepiment will alternate with the stigma:* — for the stigma is the extremity of the midrib of the carpellary leaf, or of the dorsal suture of the carpel; and the sides of either of these (which form dissepiments) will be right and left of the stigma, or in the same position with regard to the latter organ as the sides of the lamina of a leaf to its apex. Let the triangle *a b c* represent a transverse section of a three-celled ovary, of which *d*, *e*, *f* are the dissepiments. The stigmas would occupy a position equal to that of the spaces *s*, *s*, *s*, and would consequently be alternate with *d*, *e*, *f*, the dissepiments: they could not possibly be placed opposite *d*, *e*, *f*, upon any principle of structure with which we are acquainted. This law proves that neither the membrane which separates the two cells of a cruciferous siliqua, nor the vertical plate that divides the ovary of Astragalus into two equal portions, are dissepiments; both are expansions of the placenta, or of some other part, in different degrees.

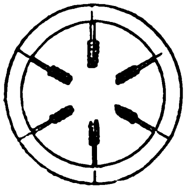
131



All partitions whose position is at variance with the foregoing laws are spurious. Such *spurious dissepiments* are caused by many circumstances, the chief of which are the following:—they are caused by expansions of the placenta, as in Cruciferæ, when they form a partition stretching from one side to the other of the fruit; or they are mere dilatations of the lining of the pericarp, as in Cathartocarpus Fistula, in which they are horizontal; or they are internal expansions of the dorsal or ventral suture, as in Amelanchier, Astragalus, and Thespesia, in which they are distinguishable from the dissepiments by not bearing the placentæ, and by being opposite the stigma, or by projecting beyond the placentæ; or, finally, they are caused by the sides of the ovary projecting into the cavity, uniting and forming many supernumerary cells, as in Diplophractum.

Such is the structure of an ovary in its most common state; certain deviations from it remain to be explained. We have seen that when carpels become syncarpous, they form a pistil, the ovary of which has as many cells and dissepiments as there are carpels employed in its construction. But sometimes the united sides of the carpels do not project so far into the cavity of the ovary as to meet in the axis; and then the result is an ovary, which, although composed of many carpels, is nevertheless one-celled (*fig.* 132.). In such case the dissepiments project a short distance only beyond the inner lining, or *paries*, of the ovary, and, bearing on their edges the placentæ, the latter are said to be parietal. In other plants, such as Corydalis, Viola, and Orchis, the carpels are not folded together at all, but are spread open and united by their edges (*fig.* 133.): in that case the placentæ do not project at all into the cavity of the ovary, but are still more strictly parietal than the last.

132



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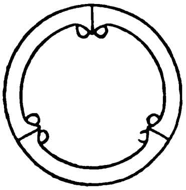

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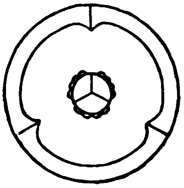


Another class of anomalies, of a still more remarkable character, is that in which there are no dissepiments, while the placentæ form a distinct mass in the centre of the ovary, as in Lychnis; this is what is called a *free central placenta* (*fig.* 134.). But, if we examine these plants at a very early period of their formation, long before the flowers expand, the explanation of the anomaly is sometimes not difficult. It will be found that such plants as Alsinaceæ have, at that time, their dissepiments meeting in the centre, and forming there a fungous placenta; but subsequently the shell of the ovary grows more rapidly than the dissepiments, and breaks away from them; while the excessive growth of the placenta afterwards destroys almost all trace of them: their previous presence is only to be detected by lines upon the shell of the ovary, or by the separation of the mass of ovules into distinct parcels upon the placenta.

It seems to me difficult to explain the *usual* nature of the pistil and its parts more simply or in a more satisfactory manner than this; but Schleiden altogether objects to that part which attributes the placenta to the developement of ovules upon the edge of a carpel, or from a carpel at all. He maintains that the formation of the ovule in Taxus, — where it terminates a branch, and is naked, and where the leaves are arranged in the customary spiral direction, even to the extreme summit, and where no one leaf implies in the slightest degree an adaptation to the female part more than another, — is incompatible with this theory; and he also adverts to the difficulty of explaining by it such a structure as that of Armeria, in which five carpels surround a single ovule, rising from the bottom of a cell upon a cord, which curves downwards at its apex, and thus suspends the ovule free in the centre of the cavity; he therefore supposes the ovule, and consequently the placenta, to be in all cases a production of the axis. As the opinions of Dr. Schleiden are in my mind always deserving of great attention, I extract a rather long passage from his paper on this subject.

" Although we cannot doubt that in plants possessing a free central placenta, or in those where, as in the Polygonaceæ, Taxus, Juglans, Myrica, the placenta cannot be supposed to exist as a separate organ, the nucleus of the ovule is only the summit of the axis, yet the question suggests itself as to how the parietal placenta is to be understood; and I do not consider the explanation to be very difficult. We find in many Araceæ that the axis is expanded at its summit into a kind of disc, upon which is a number of buds or ovules, arranged like the flowers in the capitulum of Compositæ and other families. We next observe these discs expanded into lobed processes, and adherent to the edges of the carpellary leaves in all parietal or pseudocentral placenta; such a modification of the axis as this is what occurs in Dorstenia. The parietal placenta may be explained equally well, and perhaps with greater simplicity, as a mere ramification of the axis. It will not therefore surprise us that the buds or ovules of these branches grow only upon their inner side, viz. that side directed towards the axis; for the same is observed in the inflorescence of many plants, for instance, in Æsculus. Lastly, in those plants in which the entire wall of the simple ovarium is occupied with ovules, we find the axis expanded somewhat in the shape of a basin, as may also be seen in the similar modification of the stalk in many Rosaceæ and in Ficus.

"We find moreover in nature, that in parietal placentæ the edges of the leaves are never laid upon one another throughout their entire length, and so adhere to each other; but they become united from below upwards, by the subsequent growth of a more or less distinctly intermediate substance. This substance is very evident in the Fumariaceæ and Cruciferæ, in which it appears much later than the carpellary leaves, stands exactly within them, and in the latter family forms the spurious partition, by its gradual extension towards the middle, and its subsequent adhesion. The placenta shows itself to be independent of the carpellary leaves, during its growth, most strikingly in the Abietineæ. My investigations of the earliest conditions have shown me that the organ which, since the researches of R. Brown, has been considered as an open ovarium, is only a scale-like expanded placenta; and that the organ which R. Brown has named bractea is the actual carpellary leaf. This result has been confirmed to me, in a most beautiful manner, by a cone of Pinus alba, which upon the upper half was covered with female, and upon the lower with male, flowers. In the Abietineæ, the placenta, left without the least constraint, developes itself to such an extent, that at length the carpellary leaf itself appears as a mere supplementary part."

Similar views are entertained by Schykofsky, a Russian botanist, who has written a memoir upon the subject in the *Bulletin de la Société Imp. des Naturalistes de Moscou*, 1837, No. 5. p. 1. tt. 1. and 2.; but, as it is published in the Russian language, I am unable to state the tendency of his arguments. I may also remark that Schleiden's theory is much in accordance with the ideas of the late Professor Richard.

There is undoubtedly a great deal of force in these arguments, and it is extremely probable that the ovule with its placenta is a developement of the axis, and not of the margin of a carpellary leaf, in numerous instances where its origin has been hitherto supposed to be of the latter kind; especially in Compositæ, Graminaceæ, Polygonaceæ, Plumbaginaceæ, Primulaceæ, &c. But it does not follow that, because the placenta has sometimes, it must always have, such an origin. We know that leaves do produce buds, we also know that the axis produces them; there is therefore no reason why the carpels, as well as the point of the axis which they enclose or surround, should not in like manner produce ovules. In fact we have numerous cases of monsters, especially in Crassulaceæ, Amygdaleæ, and Ranunculaceæ, in which the ovules do most certainly grow on the margins of leaves only partially converted into carpels. Moreover Dr. Grisebach, in his excellent *Genera et Species Gentianearum*, has shown that the placenta of that order cannot be an expansion of the axis, because the ovula are originally developed in two or three rows on the face of the carpels, forming a line of minute tumours from the base to half-way up the carpels; "quæ quidem series, parenchymate magis inter ovula quam in dorso *carpophylli* crescente, demùm ipsius superficiem ferè integram subæqualiter obtegunt."

Dr. Schleiden disregards the cases on record of leaves producing buds: but he will probably reconsider his opinions upon that point.

12. Of the Receptacle.

The part upon which the carpels are seated is the apex of the peduncle, or the summit of the floral branch, of which the carpels are the termination. Usually this part, which is called the receptacle, is flat, or merely a vanishing point; but in other cases it is very much dilated, and then assumes a variety of curious appearances. This receptacle is called *torus*, or *thalamus* as well as *receptaculum*, and in Greek compounds has the name of *clinium.*

In Anonaceæ and Magnoliaceæ it elevates itself from the base of the calyx, and bears the numerous stamens peculiar to these orders: here it is called *gonophore* (gonophorum) by De Candolle. When it is succulent and much dilated, so as to resemble the receptacle of a Composita, bearing at the same time many ovaries, as in the Strawberry and Raspberry, Richard calls it *polyphore:* most commonly such a receptacle is sufficiently described by the adjective fleshy. If only a single row of carpels developes upon such a receptacle, as in Ochna, and there is an oblique inclination of the carpels towards the axis of the flower, we have the *gynobase* (Plate V. fig. 3. *a*); in the Geranium this part is remarkable for being lengthened into a tapering woody cone to which the styles adhere in the form of a beak; in Nelumbium it is excavated into a number of cavities, in which the ovaries are half-hidden. It may be conjectured that the receptacle is in reality the growing point of the flower bud, and that it is analogous to the spongy head of the spadix in Arum, and to the hard spines of the Blackthorn.

In Caryophylleæ an internode below the receptacle is elongated, and bears on its summit the petals and stamens: De Candolle calls this *anthophore* (anthophorum).

13. Of the Ovule.

The *Ovule* (Plate V. fig. 16. to 26.) is a small, semipellucid, pulpy body, borne by the placenta, and gradually changing into a seed. Its internal structure is difficult to determine, both in consequence of its minuteness, and of the extreme delicacy of its parts, which are easily torn and crushed by the dissecting knife. It is doubtless owing to this circumstance chiefly, that the anatomy of the ovule was almost unknown to botanists of the last century, and that it has only begun to be understood within ten or twelve years, during which it has received ample illustration from several skilful observers. Brown, indeed, claims to have pointed out its real nature so long ago as 1814; but the brief and incomplete terms then used by that gentleman, in the midst of a long description of a single species, in the Appendix to Captain Flinders's *Voyage*, unaccompanied as they were by any explanatory remarks, prove indeed that he knew something of the matter, but by no means entitle him to the credit of having, at that time, made the world acquainted with it. The late Mr. Thomas Smith seems to deserve the honour of having first made any *general* remarks upon the subject: of what extent they exactly were is not known, as his discoveries, in 1818, were communicated, as it would seem, in conversation only; but it is to be collected from Brown's statement that they were of a highly important nature. Since that period the structure of the ovule has received much attention from Brown, in England; Turpin and Adolphe Brongniart, in France; and Treviranus, in Germany; by all of whom the subject has been greatly illustrated. It is, however, to Mirbel, — who, by collecting the discoveries of others, examining their accuracy, and combining them with numerous observations of his own, has given a full account of the gradual developement and the different modifications of the ovule — that we are indebted for by far the best description of that important organ. His two papers read before the Academy of Sciences at Paris, in 1828 and 1829, are a model of careful investigation.

Ovules have been compared to buds, and may be shown to be analogous to them in structure. Of the truth of this there can now be little doubt: for, to say nothing of such plants as Bryophyllum, which habitually form buds on the margins of the leaves; or of Malaxis paludosa, in which the edge of the leaf is frosted by little microscopical points, that are neither exactly ovules nor exactly buds; or of the bracts of Marcgraavia, which Turpin, with much ingenuity, has endeavoured by mere argumentation to prove analogous to the primine of the ovule; it has been shown by Henslow that in the Mignionette the ovules do actually become transformed into leaves, either solitary or rolled together round an axis, of which the nucleus is the termination. (*Cambr. Phil. Trans.* vol. v. part i.) Engelman, also, mentions and figures instances of similar changes; but he does not say in what plants, nor are his figures satisfactory. He, however, concludes, from the observations of himself and Schimper, that " the ovules are buds of a higher order, their integuments leaves, and their stalk the axis; all which, in cases of retrograde metamorphosis, are converted into stem and green leaves." (*De Antholysi Prodromus*, § 44. 76. t. 5. f. 4, 5.) I should rather say that the evidence goes to prove that the ovule is a leaf-bud in a particular state, that the integuments are scales (i. e. rudimentary leaves) rolled up and united at their touching margins, and that the nucleus is the growing point, to which I have already on so many different occasions directed attention.

In almost all cases the ovule is enclosed within an ovary, as would necessarily happen in consequence of the convolute nature of the carpellary leaves: but if the convolution is imperfect, as in Reseda, the ovules are partially naked; and if it does not exist at all, as in Cycadaceæ and Coniferæ, the ovules are then entirely naked, and, instead of being fertilised by matter conveyed through the stigma and the style, as in other plants, are exposed to the direct influence of the pollen. This was first noticed by Brown; and, although since contradicted, seems to be perfectly true.

When the ovules are attached to the placenta by a kind of cord, that cord is called the *funiculus* (Plate V. fig. 26. *a*), and is a prolongation of the placenta.

In the beginning the ovule is a pulpy excrescence (Plate V. fig. 16.), appearing to be perfectly homogeneous, with no trace of perforation or of envelopes. But, as it advances in growth, it is gradually (Plate V. fig. 17. to 21.) enclosed in two sacs or integuments, which are open only at their apex, where, in both these sacs, a passage exists, called the *foramen* (Plate V. fig. 21. *a*); or, in the language of Mirbel, *exostome* (fig. 25. *a*) in the outer integument, and *endostome* (fig. 25. *b*) in the inner integument. The central part is a fleshy, pointed, pulpy mass, called the *nucleus* (Plate V. fig. 19, 20. *a*, 22. *b*, 23. *c*, 24. *d*, 25. *e*, 27. *e*).

The outermost of the sacs (Plate V. fig. 22. *c*, 23. *a*, 25. *c*) is called the *primine*. It is either merely a cellular coating, or it is eventually traversed by veins: these are sometimes very apparent, as in the Orange tribe, and Mirbel seems disposed to think that they often exist in a rudimentary state when they are not visible. Usually it is nearly as long as the secundine, but sometimes it is remarkably shorter, as in Euphorbia Lathyris when very young (Plate V. fig. 22.).

The outermost but one of the sacs (Plate V. fig. 23. *b*, 20. *b*, 25. *d*) is called the *secundine;* it immediately reposes upon the primine, and often contracts an adhesion with it, so that the two integuments become confounded. In order to ascertain its existence, it is, therefore, often necessary to examine the ovule at a very early period of its growth. Myrica, Alnus, Corylus, Quercus, and Juglans have been named by Mirbel as plants in which the secundine is not perceptible (Plate V. fig. 24.). Its point is usually protruded beyond the foramen of the primine.

The *nucleus* (Plate V. fig. 22. *b*, 18, 19, 20. *a*, 24. *d*, 25. *e*) is a pulpy conical mass, enclosed by the primine and secundine, and often covered by them; but frequently protruded beyond the latter, and afterwards, at a subsequent period of its growth, again covered by them. Sometimes its epidermis is said to separate in the form of a third coating called the *tercine.*

These three parts, the primine, the secundine, and the nucleus, have all an organic connection at some one point of their surface. That point is, in ovules whose parts do not undergo any alteration of direction in the course of their growth, at the base next the placenta; so that the nucleus is like a cone, growing from the base of a cup, the base of which is connected with the hilum through another cup like itself (Plate V. fig. 23.). The axis of such an ovule, which Mirbel calls *orthotropous,* is rectilinear, as in Myrica, Cistus, Urtica, &c.; and the foramen is at the end of the ovule most remote from the hilum.

But sometimes, while the base of the nucleus and that of the outer sacs continue contiguous to the hilum, the axis of the ovule, instead of remaining rectilinear, is curved down upon itself (Plate V. fig. 26, 27.); so that the foramen, instead of being at the extremity of the ovule most remote from the hilum, is brought almost into contact with it. Examples of this are found in caryophylleous plants, Mignionette, &c. Mirbel, who first distinguished these ovules, calls them *campy-*

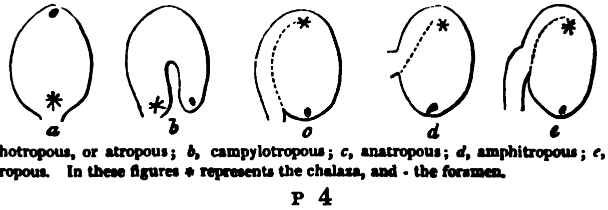
lotropous. In both these modifications, the base of the ovule and the base of the nucleus are the same.

In a third class the axis of the ovule remains rectilinear; but one of the sides grows rapidly, while the opposite side does not grow at all, so that the point of the ovule is gradually pushed round to the base; while the base of the nucleus is removed from the hilum to the opposite extremity (Plate V. fig. 16—21.): and when this process is completed the whole of the inside of the ovule is reversed; so that the apex of the nucleus, and consequently the foramen, correspond with the base of the ovule. Such ovules as these Mirbel terms *anatropous;* they are very common: examples may be found in the Almond, the Apple, the Ranunculus, the Cucumber, &c. When the base of the nucleus is thus removed from the base of the ovule, a communication between the two is always maintained by means of a vascular cord, called the *raphe* (Plate V. fig. 24. *e*, 25. *f*). This raphe, which originates in the placenta, runs up one side of the ovule, until it reaches the base of the nucleus: and there it expands into a sort of vascular disk, which is called the *chalaza* (Plate V. fig. 24. *f.* 25. *g*). As the chalaza is uniformly at the base of the nucleus, it will follow that, in orthotropous and campylotropous ovules, it is confounded with the hilum; while it is only distinguished in anatropous ones, in which alone it is distinctly to be recognised.

In addition to these there is the *amphitropous* ovule, whose foraminal and chalazal ends are transverse with respect to the hilum, which is connected with the latter by a short raphe; and the *semianatropous*, which is only different from the last, in the ovule being parallel with the funiculus instead of being at right angles with it.

The following figures give a comparative plan of these ovules.

135



a, Orthotropous, or atropous; *b*, campylotropous; *c*, anatropous; *d*, amphitropous; *e*, semianatropous. In these figures * represents the chalaza, and · the foramen.

It has been remarked that the raphe or vascular extension of the placenta always occupies the side next the ventral suture of the ovary; and that when, as in Euonymus, it is turned towards the dorsal suture, that circumstance arises from an alteration in the position of the ovule subsequent to its being fertilised.

It has also been stated that the passage through the primine and secundine is called the foramen; or the exostome, when speaking of that of the primine; and the endostome, in speaking of the secundine. Upon these Mirbel remarks:— "These two orifices are at first very minute, but they gradually enlarge; and, when they have arrived at the maximum of dilatation they can attain, they contract and close up. This maximum of dilatation is so considerable in a great number of species, in proportion to the size of the ovule, that, to give an exact idea of it, I would compare it not to a hole, as those express themselves who have hitherto spoken of the exostome and endostome, but to the mouth of a goblet or of a cup. It may therefore be easily understood, that, to perceive either the secundine or the nucleus, it is not necessary to have recourse to anatomy. I have often seen, most distinctly, the primine and secundine forming two large cups, one of which encompassed the other without entirely covering it, and the nucleus extending itself in the form of an elongated cone beyond the secundine, to the bottom of which its base was fixed."

In practical botany the detection of the foramen is often a matter of great importance; for it enables an observer to judge from the ovule of the direction of the radicle of the future embryo: it having been ascertained by many observations that the radicle of the embryo is almost always pointed to the foramen. A partial exception to this law exists, however, in Euphorbiaceæ, in many of which Mirbel has noticed that, after fertilisation, the axis of the nucleus and the endostome are inclined five or six degrees, without the exostome changing its position; by this circumstance the foramen of the secundine and that of the primine cease to correspond, and the radicle, instead of pointing when formed to the exostome, is directed to a point a short distance on one side of it.

Besides the two external integuments, Mirbel has remarked the occasional presence of three others peculiar to the nucleus, which he calls the *tercine*, *quartine*, and *quintine*.

The former is the external coat of the nucleus, and is very generally, if not universally, present. As I am unacquainted with the distinctions between these supposed integuments, especially the quartine, I can add nothing to the following remarks of Mirbel upon the subject: — "The quartine and quintine are productions slower to show themselves than the preceding. The quartine is not very rare, although no one has previously indicated it; as to the quintine, which is the *vesicula amnios* of Malpighi, the *additional membrane* of Brown, and the *sac of the embryo* of Adolphe Brongniart, I am far from thinking that it only exists in a small number of species, as Brown seems to suppose. If no one has noticed the quartine, it is, no doubt, because it has been confounded with the tercine; nevertheless these two envelopes differ essentially in their origin and mode of growth. I have only discovered the quartine in ovules of which the tercine is incorporated at an early period with the secundine; and I think that it is only in such cases that it exists. At its first appearance it forms a cellular plate, which lines all the internal surface of the wall of the cavity of the ovule; at a later period it separates from the wall, and only adheres to the summit of the cavity: at this period it is a sac, or rather a perfectly close vesicle. Sometimes it rests finally in this state, as in Statice; in other cases it fills with cellular tissue, and become a pulpy mass; under this aspect it is seen in Tulipa Gesneriana. All this is the reverse of what takes place in the tercine; for this third envelope always begins by being a mass of cellular tissue, (and at that time it has the name, as we have seen, of nucleus,) and generally finishes by becoming a vesicle.

"I have remarked the fifth envelope, or quintine, in many species: its general characters are such as to prevent its being mistaken. Its complete developement takes place only in a nucleus which remains full of cellular tissue, or in a quartine that has filled with the same. At the centre of the tissue is organised, as in a womb, the first rudiment of the quintine;

it is a sort of delicate intestine, which holds by one end to the summit of the nucleus, and by the other end to the chalaza. The quintine swells from top to bottom; it forces back on all sides the tissue that surrounds it, and it often even invades the place occupied by the quartine or the nucleus. A very delicate thread, the *suspensor* (*hypostasis* of Dutrochet), descends from the summit of the ovule into the quintine, and bears at its extremity a globule which is the nascent embryo."

It is apparently this suspensor that Brown describes, in the ovule of Orchidaceæ, as a thread consisting of a simple series of short cells, the lowermost joint or cell of which is probably the original state of what afterwards, from enlargement and deposit of granular matter, becomes the opaque speck, or rudiment of the future embryo. (*Observ. on the Organs, &c., of Orch. and Asclepiad.* pp. 18, 19.) For further information concerning the suspensor, see Mr. Griffith's observations in the chapter on FERTILISATION in Book II.

" The existence," continues Mirbel, "of a cavity in the quartine, or, indeed, the destruction of the internal tissue of the nucleus, at the period when the quintine developes, becomes the cause of some modifications in the manner of existence of this latter integument. The quintine is never seen, in certain Cucurbitaceæ, adhering to the chalaza: it is nevertheless evident that the adhesion has existed. The quintine, distended at its upper part, and suspended like a lustre from the top of the cavity, still presents at its lower end a portion of a rudimentary intestine become distinct; the separation having occurred very early, in consequence of the tearing of the tissue of the nucleus.

" The quintine of Statice is reduced to a sort of cellular placenta, to the lower surface of which the embryo is attached. This abortion of the quintine arises from the quartine having a large internal cavity, which prevents the young quintine from placing itself in communication with the chalaza, and taking that developement which it acquires in a multitude of other species."

I have continued in this edition to quote the preceding statements of Mirbel; but I have great doubt of their accuracy in some respects, and Schleiden asserts that Mirbel has not clearly understood what he saw, and that the best account of the ovule is given by Fritzsche in Wiegmann's *Archiv.*: that, in many plants, the ovule has but one integument, as in Coniferæ, Compositæ, Lobeliaceæ, Gentianaceæ, &c.; and in others two, as in Polygonaceæ, Cistaceæ, Urticaceæ, Araceæ, and all other endogens, &c. He also appears to deny the existence of a tercine, as he expressly does that of a quartine; and I do not clearly understand whether he regards the quintine as belonging to the pollen tube, or as being the sac of the amnios, as it surely is. He moreover finds that while all endogens have two integuments of the ovule, the majority of monopetalous exogens have but one, whilst the polypetalous usually possess two. Schleiden states that "the plan which nature adopts is simply this: — The example I shall select is that of the atropous ovule, for instance of the Polygonaceæ, as being the most simple. At a certain distance below the apex of the original protuberance an ideal line may be recognised, intended as the basis of the nucleus, which does not afterwards increase in thickness. Above this line the apex forms itself into the nucleus, and below it the substance of the axis expands and forms a protuberance, which extending itself as a kind of membranous fold gradually covers in the nucleus (*Integumentum primum aut internum*, mihi; *Secundine*, Mirb.; *Membrana interna*, Auct.). Sometimes soon after, and indeed almost contemporaneously with this, sometimes later, sometimes immediately below the first protuberance, at other times at some distance from it (as, for instance, in many Polygonaceæ and Cistaceæ), we may next observe a second protuberance, which, as the second integument, covers in the first (*Integumentum secundum sive externum*, mihi; *Primine*, Mirb.; *Testa*, Auct.). The first-formed integument certainly does frequently consist only of a fold of the epidermis of the nucleus; nevertheless, we find a tolerably thick parenchyma taking part in its formation in almost all those families which form no second integument, and also in some which possess both coverings, as, for instance, in the Euphorbiaceæ, Cistaceæ, and Thymelaceæ. In the case of these three families, a peculiar process takes place; namely, upon the seed becoming ripe the external integument is gradually absorbed, until nothing but a thin membrane is left, usually described as epidermis testæ, or in the Euphorbiaceæ it has been given as arillus; and, on the other hand, the actual modified epidermis testæ has also been described as the arillus, for instance, in the Oxalideæ. The apex of the original papilla, which developes itself as nucleus, varies exceedingly in its size in proportion to the entire ovule, if examined in the different families. It often forms a long and nearly cylindrical body, as in Loasa and Pedicularis; in many cases it is shorter, so that that portion of the ovule in which no distinction has taken place between nucleus and integument (the whole being like a fleshy distended stalk) is by far the more predominant, as in all the Synanthereæ, Canna, Phlox, Polemonium: it consists, again, in some instances merely of the extreme point of the papilla itself, as in Convolvulus; or nothing more than an ideal point remains, which can no longer be distinguished as an independent body, above which, however, a protuberance developes itself, and thus forms a micropyle, as in the Dipsaceæ. Of course the process I have been describing becomes considerably modified in individual points."

Although the structure of the ovule is in general such as is above described, yet there is an exception to it of a character too remarkable to be passed over in silence. According to Mr. Griffith, the ovulum of Santalum album consists of nothing more than a naked nucleus, from within the apex of which the sac of the amnios *protrudes in the form of a long tubular process.* The same excellent botanist states that Loranthus and Viscum have an equally simple ovulum, and he considers it probable that it will hereafter appear that the sac of the amnios is the only essential part of an ovule. (*Linn. Trans.* xviii. 77.)

The fluid matter contained within the nucleus is called the *liquor amnios*, and is supposed to be what nourishes the embryo during its growth.

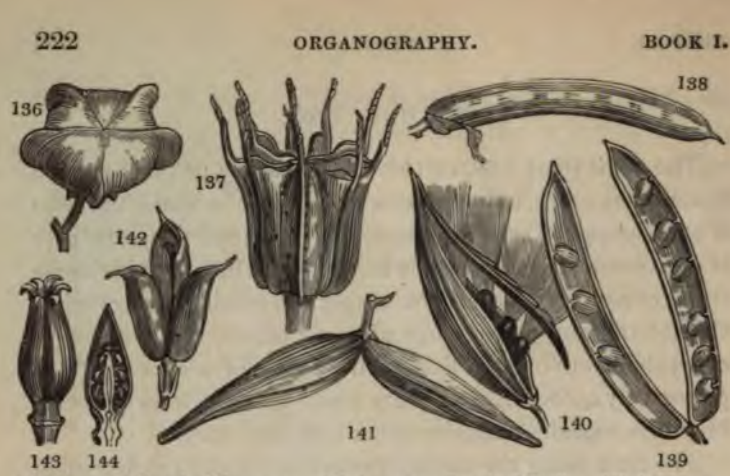
When an ovule grows erect from the base of the ovary, it is called *erect;* when from a little above the base, *ascending;* when it hangs from the summit of the cavity, it is *pendulous;* and when from a little below the summit, it is *suspended.*

14. Of the Fruit.

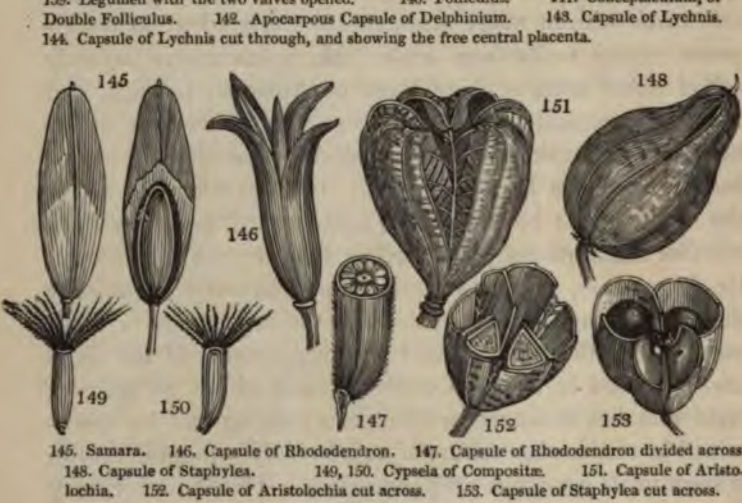
The *fruit* (*figs.* 136. to 168.) is the ovary or pistil arrived at maturity; but, although this is the sense in which the term is strictly applied, yet in practice it is extended to whatever is combined with the ovary when ripe. Thus the pine-apple fruit consists of a mass of bracts, calyxes, corollas, and ovaries; that of the nut, the acorn, and many others, of the superior dry calyx and ovary; that of the apple of a succulent superior calyx, corolla, and ovary; and that of the strawberry-blite of a succulent inferior calyx and dry ovary.

The fruit being the matured ovary, it should exhibit upon some part of its surface the traces of a style or stigma; and this mark will, in many cases, enable the student to distinguish minute fruits from seeds. Many fruits were formerly called *naked seeds*, such as those of Apiaceæ, Labiatæ, and Boraginaceæ, and the grain of corn; but, now that attention has been paid to the gradual developement of organs, such errors have been corrected. In cases where a trace of the style cannot be discovered, anatomy will generally show whether a minute body is a seed or fruit, by the presence, in the latter case, of two separable and obviously organically distinct coatings to the nucleus of the seed; but in other cases, where the pericarp and the integuments of the seeds are combined in a single covering, and where no trace of style remains, as sometimes happens, nothing can be determined as to the exact nature of a given body without following it back in its growth to its young state. This, however, may be stated, that naked seeds, properly so called, are not known to exist in more than three or four orders in the whole vegetable kingdom; viz. in Coniferæ and Cycadaceæ, where the ovules also are naked, and in Peliosanthes Teta and Leontice, in which the ovules, originally enclosed in an ovary, rupture it at an early period after fertilisation, and subsequently continue naked until they become seeds.

Such being the case, it follows that all the laws of structure which exist in the ovary are equally to be expected in the fruit; and this fact renders a repetition in this place of the general laws of formation unnecessary. Nevertheless, as, in

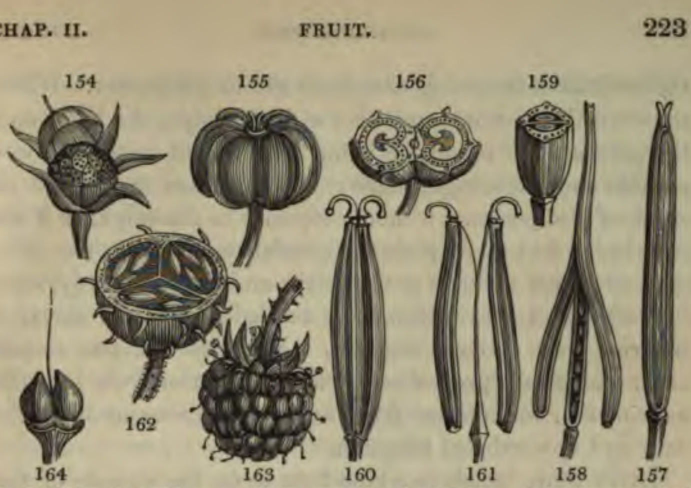


136 Syncarpous Capsule of Euonymus. 137. Apocarpous Capsule of Nigella. 138. Legumen. 139. Legumen with the two valves opened. 140. Folliculus. 141. Conceptaculum, or Double Folliculus. 142. Apocarpous Capsule of Delphinium. 143. Capsule of Lychnis. 144. Capsule of Lychnis cut through, and showing the free central placenta.

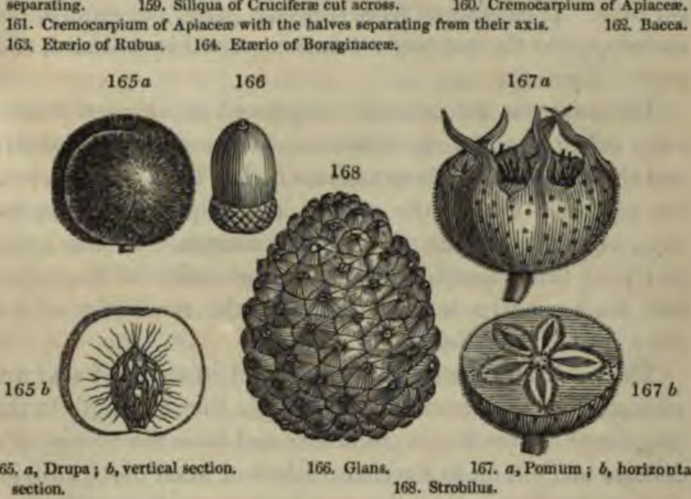


145. Samara. 146. Capsule of Rhododendron. 147. Capsule of Rhododendron divided across 148. Capsule of Staphylea. 149, 150. Cypsela of Compositæ. 151. Capsule of Aristolochia. 152. Capsule of Aristolochia cut across. 153. Capsule of Staphylea cut across.

the course of the advance of the ovary to maturity, many changes often occur which contribute to conceal the real structure of the fruit, it is in all cases advisable, and in many absolutely necessary, to examine the ovary, in order to be certain of the exact construction of the fruit itself. These changes are caused by the abortion, non-developement, obliteration, addition, or union of parts. Thus the three-celled six-ovuled ovary of the oak and the hazel becomes, by the non-developement of two cells and five ovules, a fruit with one seed; the three-celled ovary of the cocoa-nut is converted into a one-celled fruit, by the obliteration of two cells and



154. Pyxidium of Anagallis. 155. Cremocarpium of Apiaceæ. 156, Cremocarpium of Apiaceæ cut across. 157. Siliqua of Cruciferæ. 158. Siliqua of Cruciferæ with the valves separating. 159. Siliqua of Cruciferæ cut across. 160. Cremocarpium of Apiaceæ. 161. Cremocarpium of Apiaceæ with the halves separating from their axis. 162. Bacca. 163. Etærio of Rubus. 164. Etærio of Boraginaceæ.



165. a, Drupa ; b, vertical section. 166. Glans. 167. a, Pomum ; b, horizonta section. 168. Strobilus.

their ovules; and the two-celled ovary of some Pedaliaceæ becomes many-celled, by a division and elongation of the placentæ. In Cathartocarpus Fistula a one-celled ovary changes into a fruit having each of its many seeds lodged in a separate cell, in consequence of the formation of numerous horizontal membranes which intercept the seeds. A still more extraordinary confusion of parts takes place in the fruit of the pomegranate after the ovary is fertilised; and many other cases might be mentioned.

Every fruit consists of two principal parts, the *pericarp* and the seed, the latter being contained within the former. When the ovary is inferior, or coheres with the calyx, the latter and the pericarp are usually so completely united as to be inseparable and indistinguishable: in such cases it is usual to speak of the pericarp without reference to the calyx, as if no such union had taken place. Botanists call a fruit, the pericarp of which adheres to the calyx, an inferior fruit (*fructus inferus*); and that which does not adhere to the calyx, a superior fruit (*fructus superus*). But Desvaux has coined other words to express these ideas: a superior fruit he calls *autocarpien*; an inferior fruit, *heterocarpien*: terms unnecessary and unworthy of adoption.

Every thing which in a ripe fruit is on the outside of the real integuments of the seed, except the aril, belongs to the pericarp. It consists of three different parts, the *epicarp*, the *sarcocarp*, and the *endocarp*: terms contrived by Richard, and useful in practice.

The *epicarp* is the external integument or skin: the *endocarp*, called *putamen* by Gærtner, the inner coat or shell; and the *sarcocarp*, the intermediate flesh. Thus, in the peach, the separable skin is the epicarp, the pulpy flesh the sarcocarp, and the stone the endocarp or putamen. In the apple and pear the epicarp is formed by the cuticle of the calyx, and the sarcocarp is confluent with the remainder of the calyx in one fleshy body.

The *pericarp* is extremely diversified in size and texture, varying from the dimension of a single line in length to the magnitude of two feet in diameter; and from the texture of a delicate membrane to the coarse fabric of wood itself, through various cartilaginous, coriaceous, bony, spongy, succulent, or fibrous gradations.

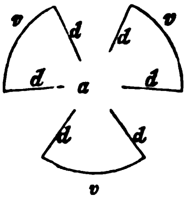
The *base* of the pericarp is the part where it unites with the peduncle; its *apex* is where the style was: hence the organic and apparent apices of the fruit are often very different, especially in such as have the style growing from their sides, as in Rosaceæ and Chrysobalanaceæ, Labiatæ and Boraginaceæ.

When a fruit has arrived at maturity, its pericarp either continues perfectly closed, when it is *indehiscent*, as in the hazel nut; or separates regularly round its axis, either wholly or partially, into several pieces: the separation is called *dehiscence*, and such pieces *valves;* and the axis from which the valves separate, in those cases where there is a distinct axis, is called the *columella.*

When the dehiscence takes place through the dissepiments, it is said to be *septicidal;* when through the back of the cells, it is called *loculicidal;* if along the inner edge of a simple fruit it is called *sutural;* if the dissepiments are separated from the valves, the dehiscence is named *septifragal.*

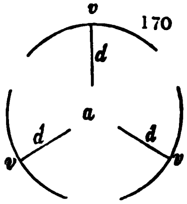
In *septicidal* dehiscence the dissepiments divide into two plates and form the sides of each valve, as in Rhododendron, Menziesia, &c. Formerly botanists said that in this sort of dehiscence the valves were alternate with the dissepiments, or that the valves had their margins turned inwards. This may be understood from *fig.* 169., which represents the relative position of parts in a transverse section of a fruit with septicidal dehiscence; *v* being the valves, *d* the dissepiments, and *a* the axis.

169



In *loculicidal* dehiscence the dissepiments form the middle of each valve, as in the lilac, or in the diagram 170., where the letters have the same value as above. In this it was formerly said that the dissepiments were opposite the valves.

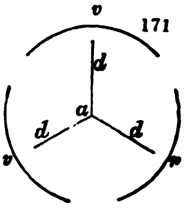
170



In *septifragal* dehiscence the dissepiments adhere to the axis and separate from the valves, as in Convolvulus; or in the diagram 171., lettered as before.

In *sutural* dehiscence there are no dissepiments, the fruit being composed of only one carpel, as the Pea.

171



Besides these regular forms of valvular dehiscence, there is a mode which obtains in a very few plants, called *circumscissile.* This occurs by a transverse circular separation, as in Anagallis; in Jeffersonia it only takes place half round the fruit.

Valvular dehiscence, which is by far the most common mode by which pericarps open, must not be confounded with either *rupturing* or *solubility*,—irregular and unusual contrivances of nature for facilitating the dispersion of seeds. In valvular dehiscence the openings have a certain reference to the cells, as has been already shown; but neither rupturing nor solubility bear any distinct relation to the cells. ***Rupturing*** consists in a spontaneous contraction of a portion of the pericarp, by which its texture is broken through, and holes formed, as in Antirrhinum and Campanula. ***Solubility*** arises from the presence of certain transverse contractions of a one-celled pericarp, through which it finally separates into several closed portions, as in Ornithopus.

For the nature of the placenta and umbilical cord see the observations under ovary. These parts, which are mere modifications of each other, essentially appertain to the pericarp, in which the former often acquires a spongy dilated substance, occasionally dividing the cells by spurious dissepiments, and often giving to the fruit an appearance much at variance with its true nature. In some seeds, as Euonymus europæus, it becomes exceedingly dilated around each seed, forming an additional envelope, called *aril*. The true character of this organ was unknown till it was settled by Richard: before his time the term was applied, not only in its true sense to an enlargement of the placenta, but also to the endocarp of certain Rubiaceæ and Rutaceæ, to the seed-coat of Jasminum, Orchideæ, and others, and even to the perianth of Carex. A very remarkable instance of the aril is to be found in the nutmeg, in which it forms the part called the *mace* surrounding the seed. It is never developed until after the fertilisation of the ovule.

Having thus explained the structure of the pericarp, it is in the next place necessary to enquire into the nature of its modifications, which in systematic botany are of considerable importance. It is, on the one hand, very much to be regretted that the terms employed in this department of the science, which is that of Carpology, have been often used so vaguely as to have no exact meaning; while, on the other hand, they have been so exceedingly multiplied by various writers, that the language of carpology is a mere chaos. In practice but a small number of terms is actually employed; but it cannot be doubted that, if it were not for the inconvenience of overburdening the science with words, it would conduce very much to clearness of description if botanists would agree to make use of some very precise and uniform nomenclature.

What, for instance, can be more embarrassing than to find the term *nut* applied to the superior plurilocular pericarp of Verbena, the gland of Corylus, and the achenia of Rosa and Borago; and that of *berry* to the fleshy envelope of Taxus, the polyspermous inferior fruit of Ribes, the succulent calyx of Blitum, and several other things?

So much discordance, indeed, exists in the application of terms expressive of the modifications of fruit, that it is quite indispensable to give the definitions of some of the most eminent writers upon the subject in their own words, in order that the meaning attached by those authors to carpological terms, when employed by themselves, may be clearly understood.

In the phraseology of *writers antecedent to Linnæus*, the following are the only terms of this description employed; viz.—

1. *Bacca*, a berry: any fleshy fruit.
2. *Acinus*, a bunch of fleshy fruit: especially a bunch of grapes.
3. *Cachrys*, a cone: as of the pine tree.
4. *Pilula*, a cone like the Galbulus of modern botanists.
5. *Folliculus* (Fuchs), any kind of capsule.
6. *Grossus*, the fruit of the fig unripe.
7. *Siliqua*, the coating of any fruit.

In his *Philosophia Botanica*, LINNÆUS gives the following definitions of the terms he employs: —

1. *Capsula*, hollow, and dehiscing in a determinate manner.
2. *Siliqua*, two-valved, with the seeds attached to both sutures.
3. *Legumen*, two-valved, with the seeds attached to one suture only.
4. *Conceptaculum*, one-valved, opening longitudinally on one side, and distinct from the seeds.

5. *Drupa*, fleshy, without valves, containing a nut.

6. *Pomum*, fleshy, without valves, containing a capsule.

7. *Bacca*, fleshy, without valves, containing naked seeds.

8. *Strobilus*, an amentum converted into a pericarp.

GÆRTNER has the following, with definitions annexed to them: —

1. *Capsula*, a dry, membranous, coriaceous, or woody pericarp, sometimes valveless, but more commonly dehiscing with valves. Its varieties are, —

- a. *Utriculus*, a unilocular one-seeded capsule, very thin and transparent, and constantly valvular; as in Chenopodium, Atriplex, Adonis.
- b. *Samara*, an indehiscent, winged, one- or two-celled capsule; as Ulmus, Acer, Liriodendron.
- c. *Folliculus*, a double one-celled, one-valved, membranous, coriaceous capsule, dehiscing on the inside, and either bearing the seed on each margin of its suture, or on a receptacle common to both margins; as Asclepias, Cinchona, and Vinca.

2. *Nux*, a hard pericarp, either indehiscent or never dividing into more than two valves; as in Nelumbium, Boragineæ, and Anacardium.

3. *Coccum*, a pericarp of dry elastic pieces or *coccules*, as in Diosma, Dictamnus, Euphorbia.

4. *Drupa*, an indehiscent pericarp with a variable rind, very different in substance from the *putamen*, which is bony, as in Lantana, Cocos, Sparganium, Gaura, &c.

5. *Bacca*, any soft pericarp, whether succulent or otherwise; provided it does not dehisce into regular valves, nor contain a single stone adhering to it. Of this the following are kinds: —

- a. *Acinus*, a soft, succulent, semi-transparent, unilocular berry, with one or two hard seeds; as the Grape, Rivina, Rhipsalis, Rubus, Grossularia, &c.
- b. *Pomum*, a succulent or fleshy, two- or many-celled berry, the dissepiments of which are fleshy or bony, and coherent at the axis; as Pyrus, Cratægus, Cydonia, Sapota, and others.

c. *Pepo*, a fleshy berry, with the seeds attached at a distance from the axis, upon the parietes of the pericarp; as Cucumis, Stratiotes, Passiflora, Vareca, and others.

To the term bacca all other succulent fruits are referred which do not belong to Acinus, Pomum, or Pepo; as Garcinia, Caryophyllus, Cucubalus, Hedera.

6. *Legumen*, the fruit of Leguminosæ.

7. *Siliqua* and *Silicula*, the fruit of Cruciferæ.

Willdenow defines those employed by him in the following manner: —

1. *Utriculus*, a thin skin enclosing a single seed. Adonis, Galium, Amaranthus.

2. *Samara*, a pericarp containing one seed, or at most two, and surrounded by a thin membrane, either along its whole circumference, or at the point, or even at the side. Ulmus, Acer, Betula.

3. *Folliculus*, an oblong pericarp bursting longitudinally on one side, and filled with seeds. Vinca.

4. *Capsula*, a pericarp consisting of a thin coat containing many seeds, often divided into cells, and assuming various forms. Silene, Primula, Scrophularia, Euphorbia, Magnolia.

5. *Nux*, a seed covered with a hard shell which does not burst. Corylus, Quercus, Cannabis.

6. *Drupa*, a nut covered with a thick succulent or cartilaginous coat. Prunus, Cocos, Tetragonia, Juglans, Myristica, Sparganium.

7. *Bacca*, a succulent fruit containing several seeds, and not dehiscing. It encloses the seeds without any determinate order, or it is divided by a thin membrane into cells. Ribes, Garcinia, Hedera, Tilia. Rubus has a compound bacca.

8. *Pomum*, a fleshy fruit that internally contains a capsule for the seed. It differs from the celled berry in having a perfect capsule in the heart. Pyrus.

9. *Pepo*, a succulent fruit which has its seeds attached to the inner surface of the rind. Cucumis, Passiflora, Stratiotes.

10. *Siliqua*, a dry elongated pericarp consisting of two valves held together by a common permanent suture. Cruciferæ. *Silicula* is a small form of the same.

11. *Legumen*, a dry elongated pericarp consisting of two valves externally forming two sutures. Leguminosæ.

12. *Lomentum*, a legumen divided internally by spurious dissepiments, not dehiscing longitudinally, but either remaining always closed, as in Cathartocarpus fistula, or separating into pieces at transverse contractions along its length, as in Ornithopus.

The following are enumerated as *spurious fruits* : —

13. *Strobilus*, an Amentum the scales of which have become woody. Pinus.

14. *Spurious capsule*. Fagus, Rumex, Carex.

15. *Spurious nut*. Trapa, Coix, Mirabilis.

16. *Spurious drupe*. Taxus, Anacardium, Semecarpus.

17. *Spurious bacca*. Juniperus, Fragaria, Basella.

By this author the names of fruits are, perhaps, more loosely and inaccurately applied than by any other.

Link objects to applying particular names to variations in anatomical structure; observing, "that botanists have strayed far from the right road in distinguishing these terms by characters which are precise and difficult to seize. Terms are only applied to distinct parts, as the leaf, peduncle, calyx, and stamens, and not to modifications of them. Who has ever thought of giving a distinct name to a labiate or papilionaceous corolla, or who to a pinnated leaf?" But this sort of reasoning is of little value, if it is considered that the fruit is subject to infinitely greater diversity of structure than any other organ, and that names for these modifications have become necessary, for the sake of avoiding a minute explanation of the complex differences upon which they depend. Besides, to admit, as Link actually does, such names as capsula, &c., is abandoning the argument; and when the following definitions, which this learned botanist has proposed, are considered, I think that little doubt will exist as to whether terms should be employed in the manner recommended by himself, or with the minute accuracy of the French. According to Professor Link, the following are the limits of carpological nomenclature : —

1. *Capsula*, any dry, membranous, or coriaceous, pericarp.

2. *Capsella*, the same, if small and one-seeded.

3. *Nux*, externally hard.
4. *Nucula*, externally hard, small, and one-seeded.
5. *Drupa*, externally soft, internally hard.
6. *Pomum*, fleshy or succulent, and large.
7. *Bacca*, fleshy or succulent, and small.
8. *Bacca sicca*, fleshy when unripe, dry when ripe, and then distinguishable from the capsule by not being brown.
9. *Legumen*, } the pericarps of certain natural orders.
10. *Siliqua*, }
11. *Amphispermium*, a pericarpium which is of the same figure as the seed it contains.

In more recent times there have been three principal attempts at classing and naming the different modifications of fruit; namely, those of Richard, Mirbel, and Desvaux. These writers have all distinguished a considerable number of variations, of which it is important to be aware for some purposes, although their nomenclature is not much employed in practice. But, in proportion as the utility of a classification of fruit consists in its theoretical explanation of structure rather than in a strict applicability to practice, it becomes important that it should be founded upon characters which are connected with internal and physiological distinctions rather than with external and arbitrary forms. Viewing the subject thus, it is not to be concealed, that, notwithstanding the undoubted experience and talent of the writers just mentioned, their carpological systems are essentially defective. Besides this, each of the three writers has felt himself justified in contriving a nomenclature at variance with that of his predecessors, for reasons which it is difficult to comprehend.

If a complete carpological nomenclature is to be established, it ought to be carried farther than has yet been done, and to depend upon principles of a more strictly theoretical character. I have accordingly ventured to propose a new arrangement, in which an attempt has been made to adjust the synonymes of carpological writers, and in which the names that seem to be most legitimate are retained in every case, their definitions only being altered; previously to which I shall briefly explain the methods of Richard, Mirbel, and Desvaux.

THE ARRANGEMENT OF RICHARD.

Class 1. Simple fruits.
  § 1. Dry.
    * Indehiscent.
    * * Dehiscent.
  § 2. Fleshy.
Class 2. Multiplied fruits.
Class 3. Aggregate or compound fruits.

THE ARRANGEMENT OF MIRBEL.

Class 1. Gymnocarpians. Fruit not disguised by the adherence of any other organ than the calyx.
  Ord. 1. *Carcerular.* Pericarpium indehiscent, but sometimes with apparent sutures, generally dry, superior or inferior, mostly unilocular and monospermous, sometimes plurilocular and polyspermous.
  Ord. 2. *Capsular.* Pericarpium dry, superior, or inferior, opening by valves, but never separating into distinct pieces or cocci.
  Ord. 3. *Dieresilian.* Pericarpium superior or inferior, dry, regular, and monocephalous (that is, having one common style), composed of several distinct pieces arranged systematically round a central real or imaginary axis, and separating at maturity.
  Ord. 4. *Etærionar.* Pericarps several, irregular, superior, one- or many-seeded, with a suture at the back.
  Ord. 5. *Cenobionar.* A regular fruit divided to the base into several acephalous pericarpia; that is to say, not marked on the summit by the stigmatic scar, the style having been inserted at their base.
  Ord. 6. *Drupaceous.* Pericarpium indehiscent, fleshy externally, bony internally.
  Ord. 7. *Baccate.* Succulent, many-seeded.
Class 2. Angiocarpians. Fruit seated in envelopes not forming part of the calyx.

THE ARRANGEMENT OF DESVAUX.

Class 1. Pericarpium dry.
  Ord. 1. Simple fruits.
    § Indehiscent.
    § § Dehiscent.
  Ord. 2. Dry compound fruits.
Class 2. Pericarpium fleshy.
  Ord. 1. Simple fruits.
  Ord. 2. Compound fruits.

In explanation of the principles upon which the classification of fruit which I now venture to propose is founded, it will of course be expected that I should offer some observations. In the first place, I have made it depend primarily upon the structure of the ovary, by which the fruit is of necessity influenced in a greater degree than by any thing else, the fruit itself being only the ovary matured. In using the terms simple and compound, I have employed them precisely in the sense that has been attributed to them in my remarks upon the ovary; being of opinion that, in an arrangement like the following and those which have preceded it, in which theoretical rather than practical purposes are to be served, the principles on which it depends should be conformable to the strictest theoretical rules of structure. A consideration of the fruit, without reference to the ovary, necessarily induces a degree of uncertainty as to the real nature of the fruit; the abortion and obliteration to which almost every part of it is more or less subject, often disguising it to such a degree that the most acute carpologist would be unable to determine its true structure, from an examination of it in a ripe state only. In simple fruits are stationed those forms in which the ovaries are multiplied so as to resemble a compound fruit in every respect except their cohesion, they remaining simple. But, as the passage which is thus formed from simple to compound fruits is deviated from materially when the ovaries are placed in more than a single series, I have found it advisable to constitute a particular class of such, under the name of aggregate fruit. Care must be taken not to confound these with the fourth class containing collective fruits, as has been done by more carpologists than one. While the true aggregate fruit is produced by the ovaries of a single flower, a collective fruit, if aggregate, is produced by the ovaries of many flowers; a most important difference. As the pericarp is necessarily much affected by the calyx when the two adhere so as to form a single body, it is indispensable, if a clear idea is to be attached to the genera of carpology, that inferior and superior fruits should not be confounded under the same name: for this reason I have in all cases founded a distinction upon that character.

In order to facilitate the knowledge of the limits of the genera of carpology, the following analytical table will be found convenient for reference. It is succeeded by the characters of the genera in as much detail as is necessary for the perfect understanding of their application.

Class I. Fruit simple. APOCARPI.

- One- or two-seeded:
  - Membranous, - - - - - Utriculus.
  - Dry and bony, - - - - Achænium.
  - Fleshy externally, bony internally, - - Drupa.
- Many-seeded:
  - Dehiscent:
    - One-valved, - - - - Folliculus.
    - Two-valved, - - - Legumen.
  - Indehiscent, - - - - - Lomentum.

Class II. Fruit aggregate. AGGREGATI.

- Ovaria elevated above the calyx:
  - Pericarpia distinct, - - - - Etærio.
  - Pericarpia cohering into a solid mass, - - Syncarpium.
- Ovaria enclosed within the fleshy tube of the calyx, - Cynarrhodum.

Class III. Fruit compound. SYNCARPI.

- Sect. 1. Superior:
  - A. Pericarpium dry externally:
    - Indehiscent:
      - One-celled, - - - - Caryopsis.
      - Many-celled:
        - Dry internally:
          - Apterous, - - - Carcerulus.
          - Winged, - - - Samara.
        - Pulpy internally, - - Amphisarca.
    - Dehiscent:
      - By a transverse suture, - - Pyxidium.
      - By elastic cocci, - - - Regma.

- By a longitudinal suture, - - Conceptaculum.
- By valves:
  - Placentæ opposite the lobes of the stigma:
    - Linear, - - - Siliqua.
    - Roundish, - - - Silicula.
  - Placentæ alternate with the lobes of the stigma:
    - Valves separating from the replum, Ceratium.
    - Replum none, - - Capsula.

B. Pericarpium fleshy:

- Indehiscent:
  - Sarcocarpium separable, - - Hesperidium.
  - Sarcocarpium inseparable, - - Nuculanium.
- Dehiscent, - - - - - Tryma.

Sect. 2. Inferior:

A. Pericarpium dry:

- Indehiscent:
  - Cells two or more, - - - Cremocarpium.
  - Cell one:
    - Surrounded by a cupulate involucrum, Glans.
    - Destitute of a cupula, - - Cypsela.
- Dehiscent or rupturing, . - - Diplotegia.

B. Pericarpium fleshy:

- Epicarpium hard:
  - Seeds parietal, - - - Pepo.
  - Seeds not parietal, - - - Balausta.
- Epicarpium soft:
  - Cells obliterated, or unilocular, - Bacca.
  - Cells distinct, - - - - Pomum.

Class IV. Collective fruits. ANTHOCARPI.

- Single:
  - Perianthum indurated, dry, - - - Diclesium.
  - Perianthum fleshy, - - - - Sphalerocarpium.
- Aggregate:
  - Hollow, - - - - - Syconus.
  - Convex:
    - An indurated amentum, - - - Strobilus.
    - A succulent spike, - - - Sorosis.

Class I. Fruit simple. APOCARPI.

Ovaria strictly simple; a single series only produced by a single flower.

I. Utriculus, *Gærtner*. (Cystidium, *Link.*)

One-celled, one- or few-seeded, superior, membranous, frequently dehiscent by a transverse incision. This differs from the *pyxidium* in texture, being strictly simple, *i. e.* not proceeding from an ovarium with obliterated dissepiments.

Example. Amaranthus, Chenopodium.

II. **Achænium.** (Akenium, *of many*; Spermidium; Xylodium, *Desv.*; Thecidium, *Mirb*; Nux, *Linn.*)

One-seeded, one-celled, superior, indehiscent, hard, dry, with the integuments of the seed distinct from it.

Linnæus includes this among his seeds, defining it "semen tectum epidermide osseâ." I have somewhere seen it named Spermidium; a good term if it were wanted. M. Desvaux calls the nut of Anacardium a Xylodium.

Examples. Lithospermum, Borago.

III. **Drupa.** *Drupe.* *fig.* 165. p. 223.

One-celled, one- or two-seeded, superior, indehiscent, the outer coat (*naucum*) soft and fleshy, and separable from the inner or *endocarpium* (the stone), which is hard and bony; proceeding from an ovarium which is perfectly simple. This is the strict definition of the term drupa, which cannot strictly be applied to any compound fruit, as that of Cocos, certain Verbenaceæ, and others, as it often is. Fruits of the last description are generally carcerules with a drupaceous coat. The *stone* of this fruit is the *Nux* of Richard, but not of others.

Examples. Peach, Plum, Apricot.

IV. **Folliculus.** *Follicle.* (Hemigyrus, *Desvaux*; Plopocarpium, *Desv.*) *fig.* 141.

One-celled, one- or many-seeded, one-valved, superior, dehiscent by a suture along its face, and bearing its seeds at the base, or on each margin of the suture. This differs from the legumen in nothing but its having one valve instead of two. The Hemigyrus of Desvaux is the fruit of Proteaceæ, and differs from the follicle in nothing of importance. When several follicles are in a single flower, as in Nigella and Delphinium, they constitute a form of fruit called Plopocarpium by Desvaux, and admitted into his Etærio by Mirbel.

Examples. Pæonia, Banksia, Nigella.

V. **Legumen.** *Pod.* (Legumen, *Linn.*; Gousse, *Fr.*) *fig.* 138, 139.

One-celled, one- or many-seeded, two-valved, superior, dehiscent by a suture along both its face and its back, and bearing its seeds on each margin of the ventral suture. This differs from the follicle in nothing except its dehiscing by two valves. In Astragalus two spurious cells are formed by the projection inwards of either the dorsal or ventral suture, which forms a sort of dissepiment; and in Cassia a great number of transverse diaphragms (phragmata) are formed by projections of the placenta. Sometimes the legumen is indehiscent, as in Cathartocarpus, Cassia fistula, and others; but the line of dehiscence is in such species indicated by the presence of sutures. When the two sutures of the legumen separate from the valves, they form a kind of frame called *replum*, as in Carmichaelia.

Examples. Bean, Pea, Clover.

VI. **Lomentum.** (Legumen lomentaceum, *Rich.*)

Differs from the legumen in being contracted in the spaces between such seed, and there separating into distinct pieces; or indehiscent, but divided by internal spurious dissepiments, whence it appears at maturity to consist of many articulations and divisions.

Example. Ornithopus.

Class II. Fruit aggregate. AGGREGATI.

Ovaria strictly simple; more than a single series produced by each flower.

VII. Etærio, *Mirb.* ("Polychorion, *Mirb.*;" Polysecus, *Desvaux*; Amalthea, *Desv.*; Erythrostomum, *Desvaux.*) *fig.* 163.

Ovaries distinct; pericarpia indehiscent, either dry upon a dry receptacle, as Ranunculus, dry upon a fleshy receptacle, as Strawberry, or fleshy upon a dry receptacle, as Rubus. The last is very near the syncarpium, from which it differs in the ovaria not coalescing into a single mass. It is Desvaux's Erythrostomum. This term is applied less strictly by M. Mirbel, who admits into it dehiscent pericarpia, not placed upon an elevated receptacle, as Delphinium and Pæonia; but the fruit of these plants is better understood to be a union of several follicules within a single flower. If there is no elevated receptacle, we have Desvaux's Amalthea. The parts of an Etærio are Achenia.

Examples. Ranunculus, Fragaria, Rubus.

VIII. Syncarpium. (Syncarpium, *Rich.*; Asimina, *Desv.*)

Ovaries cohering into a solid mass, with a slender receptacle.

Examples. Anona, Magnolia.

IX. Cynarrhodum. (Cynarrhodum, *Officin. Desvaux.*)

Ovaries distinct; pericarpia hard, indehiscent, enclosed within the fleshy tube of a calyx.

Examples. Rosa, Calycanthus.

Class III. Fruit compound. SYNCARPI.

Ovaria compound.

Sect. 1. Fruit superior.

A. Pericarpium dry.

X. Caryopsis. (Cariopsis, *Rich.*; Cerio, *Mirb.*)

One-celled, one-seeded, superior, indehiscent, dry, with the integuments of the seed cohering inseparably with the endocarpium, so that the two are undistinguishable; in the ovarium state evincing its compound nature by the presence of two or more stigmata; but nevertheless unilocular, and having but one ovulum.

Examples. Wheat, Barley, Maize.

XI. Regma, *Mirb.* (Elaterium, *Rich.*; Capsula tricocca, *L.*)

Three or more celled, few-seeded, superior, dry, the cells bursting from the axis with elasticity into two valves. The outer coat is frequently softer than the endocarpium or inner coat, and separates from it when ripe; such regmata are drupaceous. The cells of this kind of fruit are called *cocci*.

Example. Euphorbia.

XII. Carcerulus, *Mirb.* (Dieresilis, *Mirb.*; Cœnobio, *Mirb.*; Synochorion, *Mirb.*; Sterigmum, *Desvaux*; Microbasis, *Desvaux*; Polexostylus, *Mirb.*; Sarcobasis, *Dec.*, *Desv.*; Baccaularius, *Desv.*)

Many-celled, superior: cells dry, indehiscent, few-seeded, cohering by a common style round a common axis. From this the Dieresilis of Mirbel does not differ in any essential degree. The same writer calls the fruit of Labiatæ (*fig.* 162.), which Linnæus and his followers mistake for naked seeds, Cœnobio: it differs from the Carcerulus in nothing but the low insertion of the style into the ovaria, and the distinctness of the latter.

Examples. Tilia, Tropæolum, Malva.

XIII. Samara, *Gærtn. Key.* (Pteridium, *Mirb.*; Pterodium, *Desv.*), *fig.* 145.

Two or more celled, superior; cells few-seeded, indehiscent, dry; elongated into wing-like expansions. This is nothing but a modification of the Carcerule.

Examples. Fraxinus, Acer, Ulmus.

XIV. Pyxidium. (Pyxidium, *Ehr.*, *Rich.*, *Mirb.*; Capsula circumscissa, *L.*) *fig.* 154.

One-celled, many-seeded; superior, or nearly so; dry, often of a thin texture; dehiscent by a transverse incision, so that when ripe the seed and their placenta appear as if seated in a cup, covered with a lid. This fruit is one-celled by the obliteration of the dissepiments of several carpella, as is apparent from the bundles of vessels which pass from the style through the pericarpium down into the receptacle.

Example. Anagallis.

XV. Conceptaculum. (Conceptaculum, *Linn.*; Double Follicule, *Mirb.*) *fig.* 141.

Two-celled, many-seeded, superior, separating into two portions, the seeds of which do not adhere to marginal placentæ, as in the folliculus, to which this closely approaches, but separate from their placentæ, and lie loose in the cavity of each cell.

Examples. Asclepias, Echites.

XVI. Siliqua, *Linn. fig.* 157, 158, 159.

One- or two-celled, many-seeded, superior, linear, dehiscent by two valves separating from the replum; seeds attached to two placentæ adhering to the replum, and *opposite* to the lobes of the stigma. The dissepiment of this fruit is considered a spurious one formed by the projecting placentæ, which sometimes do not meet in the middle; in which case the dissepiment or phragma has a slit in its centre, and is said to be *fenestrate.*

XVII. Silicula, *Linn.*

This differs from the latter in nothing but its figure, and in containing fewer seeds. It is never more than four times as long as broad, and often much shorter.

Examples. Thlaspi, Lepidium, Lunaria.

XVIII. Ceratium. (Capsula siliquiformis, *Dec.*; Conceptaculum, *Desv.*)

One-celled, many-seeded, superior, linear, dehiscent by two valves separating from the replum; seeds attached to two spongy placentæ adhering to the replum, and *alternate* with the lobes of the stigma. Differs from the siliqua in the lobes of the stigma being alternate with the placentæ, not opposite. This, therefore, is regular, while that is irregular, in structure.

Examples. Glaucium, Corydalis, Hypecoum.

XIX. Capsula. *Capsule. fig.* 146, 147. 151, 152. 136, 137.

One- or many-celled, many-seeded, superior, dry, dehiscent by valves, always proceeding from a compound ovarium. The valves are variable in their nature: usually they are at the top of the fruit, and equal in number to the cells; sometimes they are twice the number; occasionally they resemble little pores or holes below the summit, as in the Antirrhinum.

Examples. Digitalis, Primula, Rhododendron.

XX. Amphisarca. (Amphisarca, *Desv.*)

Many-celled, many-seeded, superior, indehiscent; indurated or woody externally, pulpy internally.

Examples. Omphalocarpus, Adansonia, Crescentia.

B. Pericarpium fleshy.

XXI. Tryma. (Tryma, *Watson.*)

Superior, by abortion one-celled, one-seeded, with a two-valved indehiscent endocarpium, and a coriaceous or fleshy valveless sarcocarpium.

Example. Juglans.

XXII. Nuculanium. (Nuculanium, *Rich.*; Bacca, *Desvaux.*)

Two or more celled, few- or many-seeded, superior, indehiscent, fleshy, of the same texture throughout, containing several seeds, improperly called *nucules* by the younger Richard. This differs scarcely at all from the berry, except in being superior.

Examples. Grape, Achras.

XXIII. Hesperidium. (Hesperidium, *Desv. Rich.*)

Many-celled, few-seeded, superior, indehiscent, covered by a spongy separable rind; the cells easily separable from each other, and containing a mass of pulp, in which the seeds are embedded. The pulp is formed by the cellular tissue, which forms the lining of the cavity of the cells: this cellular tissue is excessively enlarged and succulent, is filled with fluid, and easily coheres into a single mass. The external rind is by M. De Candolle supposed to be an elevated discus of a peculiar kind, analogous to that within which the fruit of Nelumbium is seated; and perhaps its separate texture and slight connexion with the cells of the fruit seem to favour this supposition. But it is difficult to reconcile with such a hypothesis the continuity of the rind with the style and stigma, which is a sure indication of the identity of their origin; and it is certain that the shell of the ovarium and the pericarpium are the same. The most correct explanation of this structure is to consider the rind a union of the epicarp and sarcocarp, analogous to that of the drupa.

Example. Orange.

Sect. 2. Fruit inferior.

A. Pericarpium dry.

XXIV. Glans. (Glans, *Linn.*, *Desv.*; Calybio, *Mirb.*; Nucula, *Desvaux.*) *fig.* 166.

One-celled, one- or few-seeded, inferior, indehiscent, hard, dry; proceeding from an ovarium containing several cells and several seeds, all of which are abortive but one or two; seated in that kind of persistent involucre called a cupule. The pericarpium is always crowned with the remains of the teeth of the calyx; but they are exceedingly minute, and are easily overlooked. Sometimes the gland is solitary, and quite naked above, as in the common oak; sometimes there is more than one completely enclosed in the cupule, as the beech and sweet chestnut.

Examples. Quercus, Corylus, Castanea.

XXV. Cypsela. (Akena, *Necker*; Akenium, *Rich.*; Cypsela, *Mirb.*; Stephanoum, *Desv.*) *fig.* 149. 150.

One-seeded, one-celled, indehiscent, with the integuments of the seed not cohering with the endocarpium; in the ovarium state evincing its compound nature by the presence of two or more stigmata; but nevertheless unilocular and having but one ovulum. Such is the true structure of the Achenium; but as that term is often applied to the simple superior fruits, called Nux by Linnæus, I have thought it better, in order to avoid confusion, to adopt the name Cypsela.

Examples. All Compositæ.

XXVI. Cremocarpium. (Cremocarpium, *Mirb.*; Polakenium, or Pentakenium, *Rich.*; Carpadelium, *Desv.*) *fig.* 155. 160, 161.

Two- to five-celled, inferior; cells one-seeded, indehiscent, dry, perfectly close at all times; when ripe separating from a common axis. M. Mirbel confines the application of Cremocarpium to Umbelliferæ: but it is better to let it apply to all fruits which will come within the above definition. It will then be the same as Richard's Polakenium, excluding those forms in which the fruit is superior. The latter botanist qualifies his term Polakenium according to the number of cells of the fruit: thus when there are two cells it is *diakenium*, three *triakenium*, and so on. M. De Candolle calls the half of the fruit of Umbelliferæ *mericarp.*

Examples. Umbelliferæ, Aralia, Galium.

XXVII. Diplotegia. (Diplotegia, *Desv.*)

One- or many-celled, many-seeded, inferior, dry, usually bursting either by pores or valves. This differs from the capsule only in being adherent to the calyx.

Examples. Campanula, Leptospermum.

B. Pericarpium fleshy.

XXVIII. Pomum. *Apple*, or *Pome.* (Melonidium, *Rich.*; Pyridium, *Mirb.*; Pyrenarium, *Desvaux*; Antrum, *Mœnch.*) *fig.* 167.

Two or more celled, few-seeded, inferior, indehiscent, fleshy; the seeds distinctly enclosed in dry cells, with a bony or cartilaginous lining, formed by the cohesion of several ovaria with the sides of the fleshy tube of a calyx, and sometimes with each other. These ovaria are called parietal by M. Richard. Some forms of Nuculanium and this differ only in the former being distinct from the calyx.

Examples. Apple, Cotoneaster, Cratægus.

XXIX. Pepo. (Peponida, *Rich.*)

One-celled, many-seeded, inferior, indehiscent, fleshy; the seeds attached to parietal pulpy placentæ. This fruit has its cavity frequently filled at maturity with pulp, in which the seeds are embedded; their point of attachment is, however, never lost. The cavity is also occasionally divided by folds of the placenta into spurious cells, which has given rise to the belief that in Pepo macrocarpus there is a central cell, which is not only untrue but impossible.

Examples. Cucumber, Melon, Gourd.

XXX. Bacca. *Berry.* (Bacca, *L.*; Acrosarcum, *Desvaux.*) *fig.* 162.

Many-celled, many-seeded, inferior, indehiscent, pulpy; the attachment of the seeds lost at maturity, when they become scattered in the substance of the pulp. This is the true meaning of the term berry; which is, however, often otherwise applied, either from mistaking nucules for seeds, or from a misapprehension of the strict limits of the term.

Example. Ribes.

XXXI. Balausta. (Balausta, *Officin. Rich.*)

Many-celled, many-seeded, inferior, indehiscent; the seeds with a pulpy coat, and attached distinctly to their placentæ. The rind was called Malicorium by Ruellius.

Example. Pomegranate.

Class IV. Collective Fruits. ANTHOCARPI.

Fruit of which the principal characters are derived from the thickened floral envelopes.

XXXII. Diclesium. (Dyclesium, *Desvaux;* Scleranthum, *Mœnch;* Cataclesium, *Desvaux;* Sacellus, *Mirb.*)

Pericarpium indehiscent, one-seeded, enclosed within an indurated perianthium.

Examples. Mirabilis, Spinacia, Salsola.

XXXIII. Sphalerocarpum. (Sphalerocarpum, *Desv.*; Nux baccata *of authors.*)

Pericarpium indehiscent, one-seeded, enclosed within a fleshy perianthium.

Examples. Hippophäe, Taxus, Blitum, Basella.

XXXIV. Syconus. (Syconus, *Mirb.*)

A fleshy rachis, having the form of a flattened disk, or of a hollow receptacle, with distinct flowers and dry pericarpia.

Examples. Ficus, Dorstenia, Ambora.

XXXV. Strobilus. *Cone.* (Conus, or Strobilus, *Rich.*, *Mirb.*; Galbulus, *Gærtn.*; Arcesthide, *Desvaux*; Cachrys, *Fuchs*; Pilula, *Pliny.*) *fig.* 168.

An amentum, the carpella of which are scale-like, spread open, and bear naked seeds; sometimes the scales are thin, with little cohesion; but they often are woody, and cohere into a single tuberculated mass.

The Galbulus differs from the Strobilus only in being round, and having the heads of the carpella much enlarged. The fruit of the Juniper is a Galbulus, with fleshy coalescent carpella. Desvaux calls it Arcesthide.

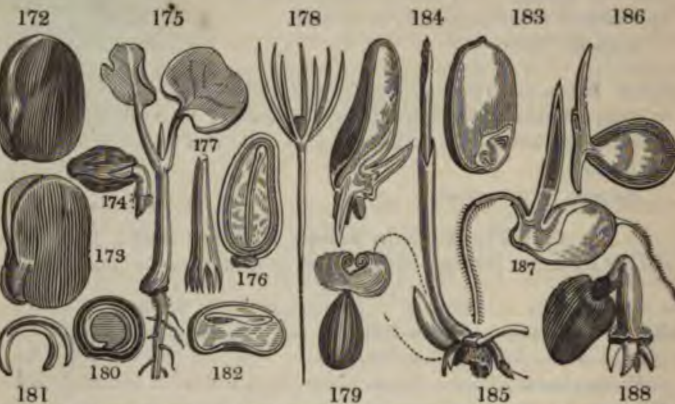
Example. Pinus.

XXXVI. Sorosis. (Sorosis, *Mirb.*)

A spike or raceme converted into a fleshy fruit by the cohesion, in a single mass, of the ovaria and floral envelopes.

Examples. Ananassa, Morus, Artocarpus.

15. Of the Seed.



172. Seed of a Garden Bean. 173. The same, after germination has just begun, and the testa is thrown off. 174. Fruit of Mirabilis Jalapa, with the embryo commencing the act of germination by protruding the radicle. 175. The same, disentangled from the pericarp, and become a young plant. 176. A section of the seed of Sterculia, with the embryo inverted in the midst of albumen. 177. The embryo of Pinus, taken out of the seed, to show its numerous cotyledons. 178. The same, after germination has advanced a little. 179. Seed of Oxalis, with the revolute elastic epidermis of the testa. 180. Seed of Salsola radiata divided vertically, and showing the annular dicotyledonous embryo, rolled round the albumen. 181. Embryo of the same, taken out of the seed. 182. Section of the seed of Cyclamen, showing the transverse embryo lying in the midst of albumen. 183. Section of the fruit of a Grass, with the lateral embryo at the base. 184. The same, with germination just beginning. 185. The same, after germination is completed, and the monocotyledonous embryo become a young plant. 186. Section of seed of Scirpus, with germination begun; the solitary cotyledon is retained within the testa, the plumule and radicle are growing beyond it. 187. Section of a Grass seed germinating; the plumula is directed upwards like a slender horn; the cotyledon is at its base, adhering to the albumen. 188. Seed of Commelina germinating; the cauliculus is protruded, is emitting radicles from its end, and has pushed aside the lid called embryotega.

As the fruit is the ovary arrived at maturity, and is therefore subject to the same laws of structure as the latter; so is the seed the ovule in its most perfect and finally organised state, and constructed upon exactly the same plan as the ovule. But as the fruit, nevertheless, often differs from the ovary in the suppression, or addition, or modification of certain portions, so is the seed occasionally altered from the precise structure of the ovule, in consequence of changes of like nature.

The seed is a body enclosed in a pericarp, is clothed with its own integuments, and contains the rudiment of a future plant. It is the point of developement at which vegetation stops, and beyond which no increase, in the same direction with itself, can take place. In a young state it has already been spoken of under the name of ovule; to which I also refer for all that relates to the insertion of seeds.

That side of a seed which is most nearly parallel with the axis of a compound fruit, or the ventral suture or sutural line of a simple fruit, is called the *face*, and the opposite side the *back*. In a compound fruit with parietal placentæ, the placenta is to be considered as the axis with respect to the seed; and that part of the seed which is most nearly parallel with the placenta, as the face. Where the raphe is visible, the face is indicated by that.

When a seed is flattened lengthwise it is said to be *compressed*, when vertically it is *depressed;* a difference which it is of importance to bear in mind, although it is not always easy to ascertain it: for this purpose it is indispensable that the true base and apex of the seed should be clearly understood. The base of a seed is always that point by which it is attached to the placenta, and which receives the name of *hilum:* the base being found, it would seem easy to determine the apex, as a line raised perpendicularly upon the hilum, cutting the axis of the seed, ought to indicate the apex at the point where the line passes through the seed-coat; but the apex so indicated would be the geometrical, not the natural apex: for discovering which with precision in seeds, the natural and geometrical apex of which do not correspond, another plan must be followed. If the skin of a seed be carefully examined, it will usually be found that it is composed in great part of lines representing rows of cellular tissue, radiating from some one point towards the base, or, in other words, of lines running upwards from the hilum and meeting in some common point. This point of union or radiation is the true apex, which is not only often far removed from the geometrical apex, but is sometimes even in juxtaposition with the hilum, as in mignionette: in proportion, therefore, to the obliquity of the apex of the seed will be the curve of its axis, which is represented by a line passing through the whole mass of the seed from the base to the apex, accurately following its curve. If the lines above referred to are not easily distinguished, another indication of the apex resides in a little brown spot or areola, hereafter to be mentioned under the name of chalaza. Where there is no indication either externally or internally of the apex, it may then be determined geometrically.

The integuments of a seed are called the *testa;* the rudiment of a future plant, the *embryo* (Plate VI. fig. 1. *b*, &c.); and a substance interposed between the embryo and the testa, the *albumen* (fig. 1. *a*, 5. *a*, &c.)

The *testa*, called also *lorica* by Mirbel, *perisperm* and *episperm* by Richard, and *spermodermis* by De Candolle, according to some consists, like the pericarp, of three portions; viz., 1. the external integument, *tunica externa* of Willdenow, *testa* of De Candolle; 2. the internal integument, *tunica interna* of Willdenow, *endopleura* of De Candolle, *hilofère* and *tegmen* of Mirbel; and, 3., of an intervening substance answering to the sarcocarp, and called *sarcodermis* by De Candolle: this last is chiefly present in seeds with a succulent testa, and by many is considered a portion of the outer integument, which is the most accurate mode of understanding it.

According to Schleiden, the integuments of the seed experience many changes during the period of ripening, so that their original number can rarely be recognised. They are sometimes all consolidated so as to form but one; or they are broken up into many layers, having no relation to the original number of integuments. In Menyanthes, which has but one integument of the ovule, the seed appears to have two, because of the separation and lignification of the epidermis of that integument; and in Canna there are five layers of tissue resembling integuments, although the ovule has not even one complete integument.

The cellular tissue of the integuments of the seed is very often reticulated. In most Bignoniaceæ, and many other plants, the epidermis is in this state, and in Casuarina there is a layer of spiral vessels below the epidermis, very thin and delicate, and extremely minute. In Swietenia febrifuga there is, below the epidermis, a thick layer of large spiral cells, which have little cohesion with each other, and which form a multitude of rather large fusiform sacs lying confusedly (?); this is the most complete case of spiral cells in seeds with which I am acquainted, and it is accompanied by the presence of a bundle of numerous slender spiral vessels in the raphe.

The *outer integument* is either membranous, coriaceous, crustaceous, bony, spongy, fleshy, or woody; its surface is either smooth, polished, rough, or winged, and sometimes is furnished with hairs, as in the cotton and other plants, which, when long, and collected about either extremity, form what is called the *coma* (sometimes also, but improperly, the pappus). It consists of cellular tissue disposed in rows, with or without bundles of vessels intermixed: in colour it is usually of a brown or similar hue: it is readily separated from the inner integument. In Maurandya Barclayana it is formed of reticulated cellular tissue; in Collomia linearis, some Salvias and others, it is caused by elastic spirally twisted fibres enveloped in mucus, and springing outwards when the mucus is dissolved. In the genus Crinum it is of a very fleshy succulent character, and has been mistaken for albumen, from which it is readily known by its vascularity. According to Brown, a peculiarly anomalous kind of partition, which is found lying loose within the fruit of Banksia and Dryandra, without any adhesion either to the pericarp or the seed, is a state of the outer integument; it is said, that in those genera the inner membrane (secundine) of the ovule is, before fertilisation, entirely exposed, the primine being reduced to half, and open its whole length; and that the outer membranes (primines) of the two collateral ovules, although originally distinct, finally contract an adhesion by their corresponding surfaces, and together constitute the anomalous dissepiment. But it may be reasonably doubted whether the integument here called secundine is not primine, and the supposed primine arillus.

The inner membrane (secundine) of the ovule, however, in general appears to be of greater importance as connected with fecundation, than as affording protection to the nucleus at a more advanced period. For in many cases, before impregnation, its perforated apex projects beyond the aperture of the testa, and in some plants puts on the appearance of an obtuse, or even dilated, stigma; while in the ripe seed it is often either entirely obliterated, or exists only as a thin film, which might readily be mistaken for the epidermis of a third membrane, then frequently observable.

" This third coat (tercine) is formed by the proper membrane or cuticle of the nucleus, from whose substance in the unimpregnated ovule it is never, I believe, separable, and at that period is very rarely visible. In the ripe seed it is distinguishable from the inner membrane only by its apex, which is never perforated, is generally acute and more deeply coloured, or even sphacelated."

Mirbel has, however, justly remarked that the primine and the secundine are, in the seed, very frequently confounded; and that, therefore, the word testa is better employed, as one which expresses the outer integument of the seed without reference to its exact origin, which is practically of little importance. The tercine is also, no doubt, often absent. He observes that these mixed integuments often give rise to new kinds of tissue; that in Phaseolus vulgaris the testa consists, indeed, of three distinct layers, but of those the *innermost* was the primine; and that the others, which represent nothing that pre-existed in the ovule, have a horny consistence, and are formed of cylindrical cellules, which elongate in the direction from the centre to the circumference. And this is probably the structure of the testa of many Leguminosæ.

It sometimes happens that the endopleura (or tercine?) thickens so much as to have the appearance of albumen, as in Cathartocarpus fistula. In such a case it is only to be distinguished from albumen by gradual observation from the ovule to the ripe seed.

One of the innermost integuments is occasionally present in the form of a fleshy sac, interposed between the albumen and the ovule, and enveloping the latter. It is what was called the *vitellus* by Gærtner, and what Richard, by a singular prejudice, considered a dilatation of the radicle of the embryo: to his macropodal form of which he referred the embryo of such plants. Instances of this are found in Nymphæa and its allies, and also in Zingiberaceæ, Peppers, and Saururus. Brown, who first ascertained the fact, considers this sac to be always of the same nature and origin, and as the *vesicula colliquamenti* or *amnios* of Malpighi.

The end by which the seed is attached to the placenta is called the *hilum* or *umbilicus* (Plate VI. fig. 5. *c*, 17. *c*, 11. *c*,

&c.); it is frequently of a different colour from the rest of the seed, not uncommonly being black. In plants with small seeds it is minute, and recognised with difficulty; but in some it is so large as to occupy fully a third part of the whole surface of the seed, as in the Horsechestnut, Sapotaceæ, and others. Seeds of this kind have been called *nauca*, by Gærtner. In grasses the hilum is indicated by a brownish spot situated on the face of the seed, and is called by Richard *spilus*. The centre of the hilum, through which the nourishing vessels pass, is called by Turpin the *omphalodium*. Sometimes the testa is enlarged in the form of irregular lumps or protuberances about the umbilicus; these are called *strophiolæ* or *carunculæ;* and the umbilicus, round which they are situated, is said to be strophiolate or carunculate. Mirbel has ascertained that in Euphorbia Lathyris the strophiole is the fungous foramen of the primine; and it is probable that such is often the origin of this tubercle: but at present we know little upon the subject.

The foramen in the ripe seed constitutes what is called the *micropyle:* it is always opposite the radicle of the embryo; the position of which is, therefore, to be determined without dissection of the seed, by an inspection of the micropyle,—often a practical convenience.

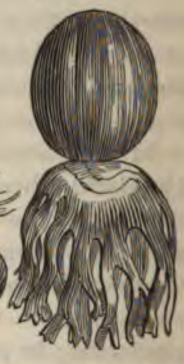
In some seeds, as the Asparagus, Commelina, and others (*fig.* 188.), there is a small callosity at a short distance from the hilum: this callosity gives way like a lid at the time of germination, emitting the radicle, and has been named by Gærtner the *embryotega.*

At the apex of the seed, in the Orange and many other plants, may be perceived upon the testa a small brown spot, formed by the union of certain vessels proceeding from the hilum: this spot is the *chalaza* (Plate VI. fig. 11. *b*). In the orange it is beautifully composed of dense bundles of spiral vessels and spiral ducts, without woody fibre. The vessels which connect the chalaza with the hilum constitute a particular line of communication, called the *raphe:* in most plants this consists of a single line passing up the face of the seed; but in many Aurantiaceæ and Clusiaceæ it ramifies upon the surface of the testa.

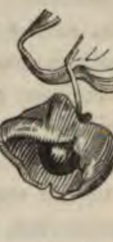
The raphe is always a true indication of the face of the seed; and it is very remarkable that the apparent exceptions to this rule only serve to confirm it. Thus, in some species of Euonymus in which the raphe appears to pass along the back, an examination of other species shows that the ovules of such species are in fact resupinate; so that, with them, the line of vascularity representing the raphe is turned away from its true direction by peculiar circumstances. In reality, the chalaza is the place where the secundine and the primine are connected; so that in *orthotropous* seeds, or such as have the apex of the nucleus at the apex of the seed, and in which, consequently, the union of the primine and secundine takes place at the hilum, there can be no apparent chalaza, and consequently no raphe: the two latter can only exist as distinct parts in anatropous or amphitropous seeds, where the base of the nucleus corresponds to the geometrical apex of the seed. Hence, also, there can never be a chalaza without a raphe, nor a raphe without a chalaza.

Something has already been said about the *aril* (*figs.* 189. and 190.) when speaking of the ovule; but it more properly comes under consideration along with the ripe seed. As a general rule, it may be stated that every thing proceeding from the placenta, and not forming part of the seed, is referable to the aril. Even in plants like Hibbertia volubilis and Euonymus europæus, in which it is of unusual dimensions, it is scarcely visible in the unimpregnated ovary; and it is stated by Brown, that he is not acquainted with any case in which it covers the foramen of the testa before impregnation. The term aril has been misapplied in many cases to the testa, as in Orchidaceæ; and even to a pair of opposite confluent bracts, as in Carex: of these errors, the former arose from imperfect observation, the latter from ignorance of the fundamental principles of Organography.

190



189



The mass enclosed within the testa or outer integument is called the *nucleus;* and consists either of *albumen* and *embryo*, or of the latter only.

The *albumen* (*perispermium*, Juss.; *endospermium*, Rich.; *medulla seminis*, Jungius; *secundinæ internæ*, Malpighi) (Plate VI. fig. 5. *a*, 1. *a*, 9. *a*, &c.), when present, is a body enclosing the embryo, and interposed between it and the integuments of the seed when there are any: it is of different degrees of hardness, varying from fleshy to bony, or even stony, as in some palms. It is in all cases destitute of vascularity, and has been usually considered as the amnios in an indurated state: but Brown is of opinion that it is formed by a deposition or secretion of granular matter in the cellules of the amnios, or in those of the nucleus itself.

The former origin is certainly that of Santalum, Viscum, and Loranthus, as traced in the progress of its formation by Mr. Griffith; but it is deserving of enquiry whether bodies of very different natures and origins are not confounded under the common name of albumen. Has, for example, the albumen of Ranunculus, and other "albuminous" exogens, the same origin as that of Solanaceæ, Scrophulariaceæ, &c.?

The albumen is often absent, is frequently much smaller than the embryo, but is also occasionally of much greater size. This is particularly the case in monocotyledons, in some of which the embryo scarcely weighs a few grains, while the albumen weighs many ounces, as in the cocoa-nut. It is almost always solid, but in Anonaceæ and Myristicaceæ it is perforated in every direction by dry cellular tissue, which appears to originate in the remains of the nucleus in which the albumen has been deposited: in this state it is said to be *ruminated*.

The *embryo* (or *corculum*) (Plate VI. fig. 1. *b*, &c.) is a fleshy body occupying the interior of the seed, and constituting the rudiment of a future plant. In most plants one embryo only is found in each seed. It nevertheless occurs, not unfrequently, that more than one is developed within a single testa, as occasionally in the Orange and the Hazel nut, and very commonly in Coniferæ, Cycas, the Onion, and the Mistletoe. Now and then a union takes place of these embryos.

It is distinguished into three parts; viz., the *radicle* (Plate VI. fig. 2. *b*, &c.) (*rhizoma* or *rostellum*); *cotyledons* (fig. 2. *a*, &c.); and *plumule* (or *gemmule*) (fig. 2. *c*.); from which is also by some distinguished the *cauliculus* or *neck* (*scapus*, *scapellus*, or *tigelle*). Mirbel admits but two principal parts; viz., the cotyledons, and what he calls the *blastema*, which comprises radicle, plumule, and cauliculus.

Upon certain differences in the structure of the embryo, modern botanists have divided the whole vegetable kingdom into three great portions, which form the basis of what is called the natural system. These are, 1. Dicotyledons; 2. Monocotyledons; and, 3. Acotyledons. In order to understand exactly the true nature of the embryo in each of these, it will be requisite first to describe it fully as it exists in dicotyledons, and then to explain its organisation in the two others.

If a common DICOTYLEDONOUS embryo (Plate VI. fig. 2.), that of the Apple for example, be examined, it will be found to be an obovate, white, fleshy body, tapering and solid at the lower end, and compressed and deeply divided into two equal opposite portions at the upper end; the lower tapering end is the *radicle*, and the upper divided end consists of two *cotyledons*. Within the base of the cotyledons is just visible a minute point, which is the *plumule*. The imaginary line of division between the radicle and the cotyledons is the *caulicule*. If the embryo be placed in circumstances favourable for *germination*, the following phenomena occur: the caulicule will extend so as to separate the cotyledons from the radicle by an interval, the extent of which varies in different plants; the radicle will become elongated downwards, forming a little root; the cotyledons will either elevate themselves above the earth and unfold, or, remaining under ground, will part with their amylaceous matter and shrivel up; and the plumule will lengthen upwards, giving birth to a stem and leaves. Such is the normal or proper appearance of a dicotyledonous embryo.

The *exceptions* to it chiefly consist, 1. in the *cohesion* of the cotyledons in a single mass, instead of their unfolding; 2. in an increase of their *number*; 3. in their occasional *absence*;

and, 4., in their *inequality*. A *cohesion* of the cotyledons takes place in those embryos which Gærtner called *pseudomonocotyledonous*, and Richard *macrocephalous*. In the Horsechestnut, the embryo consists of a homogeneous undivided mass, with a curved horn-like prolongation, of one side directed towards the hilum. If a section be made in the direction of the axis of the horn-like prolongation, through the whole mass of the embryo, a slit will be observable above the middle of the horn, at the base of which lies a little conical body. In this embryo the slit indicates the division between the two bases of a pair of opposite confluent cotyledons; the conical body is the plumule, and the horn-like prolongation is the radicle. In Castanea nearly the same structure exists, except that the radicle, instead of being curved and exserted, is straight, and enclosed within the projecting base of the two cotyledons; and in Tropæolum, which is very similar to Castanea in structure, the bases of the cotyledons, are slit into four little teeth enclosing the radicle. The germination of these seeds indicates more clearly that the cotyledonary body consists of two and not of one cotyledon; at that time the bases of the cotyledons, which had been previously scarcely visible, separate and lengthen, so as to extricate the radicle and plumule from the testa, within which they had been confined.

In *number* the cotyledons vary from two to a much more considerable number, four occur in Boraginaceæ, Brassicaceæ and elsewhere; in Coniferæ they vary from two to more than twelve.

Instances of the *absence* of cotyledons occur, 1. in Cuscuta (Plate VI. fig. 19.), to which they may be supposed to be deficient in consequence of the absence of leaves in that genus; 2. in Lentibulaceæ; and, 3., in Cyclamen, in which the radicle enlarges exceedingly. To these a fourth instance has by some been added in Lecythis, of which Richard gives the following account:—The kernel is a fleshy almond-like body, so solid and homogeneous that it is extremely difficult to discover its two extremities until germination takes place: at that period one of the ends forms a little protuberance, which subsequently bursts through the integuments of the seed, and extends itself as a root; the other end produces a scaly plumule, which in time forms the stem. The great mass of the kernel is supposed by Richard to be an enlarged radicle. I, however, see no reason for calling the two-lobed part of the embryo (Plate VI. fig. 17. *c*) a plumule, instead of cotyledons. An *inequality* of cotyledons is the most unusual circumstance with dicotyledons, and forms a distinct approach to the structure of monocotyledons: it occurs in Trapa and Sorocea, in which they are extremely disproportionate. In Cycas they are also rather unequal; but in a much less degree.

The embryo of MONOCOTYLEDONS (Plate VI. fig. I, B, &c.) is usually a solid, cylindrical, undivided, homogeneous body, slightly conical at each extremity, with no obvious distinction of radicle, plumule, or cotyledons. In *germination* the upper end swells and remains within the testa (fig. 10. C *b*, &c.); the lower lengthens, opens at the point, and emits one or more radicles: and a thread-like green body is protruded from the upper part of the portion which is lengthened beyond the testa. Here the portion remaining within the testa is a single cotyledon; the body which lengthens, producing radicles from within its point, is the cauliculus; and the thread-like protruded green part is the plumule. If this is compared with the germination of dicotyledons, an obvious difference will be at once perceived in the manner in which the radicles are produced: in monocotyledons they are emitted from within the substance of the radicular extremity, and are actually sheathed at the base by the lips of the passage through which they protrude; while in dicotyledons they appear at once from the very surface of the radicular extremity, and consequently have no sheath at their base. Upon this difference Richard proposed to substitute the term *Endorhizæ* for monocotyledons, and *Exorhizæ* for dicotyledons. Some consider the former less perfect than the latter: endorhizæ being *involute*, or imperfectly developed: exorhizæ evolute, or fully developed. Dumortier adds to these names *endophyllous* and *exophyllous;* because the young leaves of monocotyledons are evolved from within a sheath (*coleophyllum* or *coleoptilum*), while those of dicotyledons are always naked. The sheath at the base of the radicle of monocotyledons is called the *coleorhiza* by Mirbel. Another form of monocotyledonous embryo is that of Araceæ and their allies, in which the plumule is not so intimately combined with the embryo as to be undistinguishable, but is indicated externally by a little slit above the base (Plate VI. fig. 6. B *e*), within which it lies until called into developement by germination.

The *exceptions* to what has been now described ought, like those of dicotyledons, rather to be called remarkable modifications. Much stress has been laid upon them by several writers, who have thought it requisite to give particular names to their parts. To me, however, it appears far more advisable to explain their analogies without the unnecessary creation of new and bad names. In Graminaceæ (Plate VI. fig. 4.) the embryo consists of a lenticular body lying on the outside of the base of the albumen on one side, and covered on its inner face by that body, and on its outer face by the testa: if viewed on the face next the testa, a slit will be observed of the same nature as that in the side of the embryo of Araceæ; within this cleft a small conical projection is discovered, pointing towards the apex of the seed. If the embryo be then divided vertically through the conical projection, it will be seen that the latter (*c*) is a sheath including other little scales resembling the rudiments of leaves; that that part of the embryo which lies next the albumen (*d*), and above the conical body, is solid; and that the lower extremity of the embryo (*e*) contains within it the indication of an internal radicle, as in other monocotyledons. In this embryo it is to be understood that the conical projection is the *plumule;* that part of the embryo lying between it and the albumen, a single scutelliform *cotyledon;* and the lower point of the embryo, the *radicle.* In Wheat there is a second small cotyledon on the outside of the embryo, inserted a little lower down than the scutelliform cotyledon. This last is called *scutellum* by Gærtner, who thought it of the nature of vitellus. Richard considered the scutelliform cotyledon a particular modification of the radicle, and called it *hypoblastus;* the plumule a form of cotyledon, or *blastus;* the anterior occasional cotyledon a peculiar appendage, or *epiblastus;* and the radicle a protuberance of the caulicule, or *radiculoda.* He, further, in reference to this opinion, termed embryos of this description *macropodal.* In these ideas, however, Richard was wrong, as is now well known.

From what has been stated, it is apparent that dicotyledons are not absolutely characterised by having two cotyledons, nor monocotyledons by having only one. The real distinction between them consists in their endorhizal or exorhizal germination, and in the cotyledons of dicotyledons being opposite or verticillate, while they are in monocotyledons solitary or alternate. Some botanists have, therefore, recommended the substitution of other terms in lieu of those in common use. Cassini suggests *isodynamous* or *isobrious* for dicotyledons, because their force of developement is equal on both sides; and *anisodynamous* or *anisobrious* for monocotyledons, because their force of developement is greater on one side than on the other. Another writer, Lestiboudois, would call dicotyledons *exoptiles,* because their plumula is naked; and monocotyledons *endoptiles,* because their plumule is enclosed within the cotyledon; but there seems little use in these proposed changes, which are, moreover, as open to objections as the terms in common use.

In the *Library of Useful Knowledge* an apparently just explanation of the analogy between the embryo of monocotyledons and dicotyledons has been given; and I take the liberty of reproducing it here: —

"1. The embryo of an Arum is like that of a Palm, only there is a slit on one side of it through which the plumule easily escapes; 2. in Rice (Oryza) this slit is very much lengthened and widened; 3. in Barley the plumule projects beyond the slit, leaving a flat cotyledon on one side; and, 4., in Wheat the embryo has the structure of Barley, with this most important exception, that at the base of the plumule in front there is a rudimentary cotyledon, alternate with the large flat one, on the opposite side of the plumule. Hence we are to infer that the monocotyledonous embryo of a Palm *is analogous to that of a dicotyledon, of which one of the cotyledons is abstracted, and the other rolled round the plumula and consolidated at its edges.* And this is the view that must be taken of the monocotyledonous embryo in general, all the modifications of which seem reducible to this standard.

" Thus in Sea-wrack (Zostera marina), of which the embryo is an oblong almond-shaped body with a cleft on one side, in the cavity of which a long flexuose process is placed, the latter is the plumule, and the former at one end the cotyledon, and the radicle at the other; in Ruppia maritima, whose embryo is an oblong body, cut suddenly off at one end, on which a sort of curved horn crouches, the latter is the plumule, and the former chiefly cotyledon; and so in Frog-bit (Hydrocharis morsus ranæ), the embryo of which is an oblong fleshy kernel with a hole on one side, in which there lies a short cylinder, the latter is the plumule, and the former the cotyledon."

The ACOTYLEDONOUS embryo is not exactly, as its name seems to indicate, an embryo without cotyledons; for, in that case, Cuscuta would be acotyledonous. On the contrary, it is an embryo which does not germinate from two fixed invariable points, namely the plumule and the radicle, but indifferently from any point of the surface; as in some Araceæ, and in all flowerless plants. See Mohl, *Bemerkungen über die Entwicklung und den Bau der Sporen der Cryptogamischen Gewächse:* Regensb. 1833.

For further illustrations of the embryo, consult Plate VI. and the explanation of its figures.

The *direction* of the embryo is either *absolute* or *relative.* Its absolute direction is that which it has independently of the parts that surround it. In this respect it varies much in different genera; it is either straight (Plate VI. fig. 5.), arcuate (fig. 9.), falcate, uncinate, coiled up (fig. 8.) (*cyclical*), folded up, spiral (fig. 19.), bent at right angles (Plate V. fig. 28.) (*gnomonical*, Link), serpentine, or in figure like the letter S (*sigmoid*).

Its relative position is determined by the relation it bears to the chalaza and micropyle of the seed; or, in other words, upon the relation that the integuments, the raphe, chalaza, hilum, micropyle, and radicle bear to each other. If the sacs of the ovule are in no degree inverted, but have their common point of origin at the hilum, there being (necessarily) neither raphe nor chalaza visible, the radicle will in that case be at the extremity of the seed most remote from the hilum, and the embryo *inverted* with respect to the seed, as in Cistus, Urtica, and others, where it is said to be *antitropal.* But if the ovule undergoes the remarkable extension of one side already described in speaking of that organ, when the sacs are so inverted that their orifice is next the hilum, and their base at the apex of the ovule, then there will be a raphe and chalaza distinctly present; and the radicle will, in the seed, be at the end next the hilum, and the embryo will be erect with respect to the seed, or *orthotropal,* as in the Apple, Plum, &c. On the other hand, supposing that the sacs of the embryo suffer only a partial degree of inversion, so that their foramen is neither at the one extremity nor the other, there will be a chalaza and a short raphe; and the radicle will point neither to the apex nor to the base of the seed, but the embryo will lie, as it were, across it, or be *heterotropal,* as is the case in the Primrose. When an embryo is so curved as to have both apex and radicle presented to the hilum, as in Reseda, it is *amphitropal.* It is, however, becoming customary to apply to the seed the same names as those used in expressing the modifications of the ovule; this will probably become the universal practice, and then all terms referring to the position of the embryo will become superfluous.

In the words of Gærtner an embryo is *ascending* when its apex is pointed to the apex of the fruit; *descending,* if to the base of the fruit; *centripetal,* if turned towards the axis of the fruit; and *centrifugal,* if towards the sides of the fruit: those embryos are called wandering, or *vagi,* which have no evident direction.

The *cotyledons* are generally straight, and placed face to face; but there are numberless exceptions to this. Some are separated by the intervention of albumen (Plate VI. fig. 11.); others are naturally distant from each other without any intervening substance. Some are straight, some waved, others arcuate or spiral. When they are folded with their back upon the radicle, they are called *incumbent;* if their edges are presented to the same part, they are *accumbent;* terms chiefly used in speaking of Brassicaceæ.

16. Of Naked Seeds.

By naked seeds has been understood, by the school of Linnæus, small seed-like fruit, like that of Labiatæ, Boraginaceæ, Grasses, and Cyperaceæ. But as these are distinctly covered by pericarps, as has been shown above, the expression in the sense of Linnæus is obviously incorrect, and is now abandoned. Hence it has been inferred that there is no such thing in existence as a naked seed; that is to say, a seed which bears on its own integuments the organ of impregnation. To this proposition botanists had assented till the year 1825, when Brown demonstrated the existence of seeds strictly naked; that is to say, from their youngest state destitute of pericarp, and receiving impregnation through their integuments without the intervention of style or stigma, or any stigmatic apparatus. That most learned botanist has demonstrated that seeds of this description are uniform in Coniferæ and Cycadaceæ, in which no pericarpial covering exists. But we have no knowledge at present of such an economy obtaining in other plants except Gnetaceæ, as a constant character. It does, however, happen, as the same observer has pointed out, that in particular species the ovary is ruptured at an early period by the ovules, which thus, when ripe, become truly naked seeds: remarkable instances of which occur in Ophiopogon spicatus, Leontice thalictroides, and Peliosanthes Teta.

CHAPTER III.

OF THE COMPOUND ORGANS IN FLOWERLESS PLANTS, OR ACROGENS.

We have now passed in review all the different organs which exist in the most perfectly formed plants; that is to say, in those whose reproduction is provided for by the complicated apparatus of stamens and pistils, and, according to Schultz, which have latex, with its peculiar tissue. Let us next proceed to consider those lower tribes, some of which are scarcely distinguishable from animals, where there is less evident trace of sexes, in which nothing constructed like the embryo is to be detected, whose fluids have a simple motion of rotation, and which seem to have no other provision made for the perpetuation of their races than a dissolution of their cellular system. In what I may have to say about them, I shall not, however, do any thing more than give a mere enumeration and description of their organs, and an explanation of the numerous peculiar terms employed by writers in speaking of them. All speculative considerations are in this case left out of view: those who wish to be informed upon such points may consult the *Introduction to the Natural System of Botany.*

1. *Ferns.*

Filices, or Ferns, are plants consisting of a number of leaves, or *fronds* as they used to be called, attached to a stem which is either subterraneous or lengthened above the ground, sometimes rising like a trunk to a considerable height. They are the largest of known vegetables in which no organs of fructification analogous to those of phænogamous plants have been discovered. Their stems are often arborescent, acquiring as much as the height of fifty or sixty feet, or even more, and in that case are usually unbranched, of the same thickness at the upper and lower ends, and grow exclusively at the apex. The surface of the stem is often hairy or shaggy, sometimes spiny, and in all cases is more or less copiously furnished with callous points, which render it rough like shagreen leather, or covered with roots, sometimes entangled into a compact layer much thicker than the trunk itself, and appearing to be the extension of the callous points.

The anatomy of tree ferns has been skilfully elucidated by Mohl, to whose treatise upon the subject (*Martius, Plant. Crypt. Bras.* p. 40.) the reader is referred for the details of their curious organisation. I must content myself with a very general statement. The trunk is covered with a hard rind, occupying the place of bark, two or three lines thick, and consisting of hard brown parenchymatous and prosenchymatous tissue, the latter, if present, being on the inside. Within the rind is a mass of parenchymatous thinner-sided tissue, which is analogous to the horizontal cellular system of exogens and endogens. The wood is formed by concave or sinuous plates, whose section has a lunate or wavy form, and which are closely arranged in a circle next to the rind, enclosing a column of parenchyma, just as the wedges of wood in exogens enclose a similar column of pith; and in like manner there are openings between the plates, through which the subcortical and medullary parenchymas communicate. Each plate consists externally of several layers of hard brown prosenchyma, next within which is a pale stratum of thin-sided parenchyma, and in the centre of all is a soft pale mass of trachenchyma, consisting of large scalariform and spiral vessels (sometimes $\frac{1}{20}$ line in diameter) mixed with soft parenchyma. Externally the stem is marked with long, or rhomboidal scars, the surface of which is broken into numerous hard ragged projections which represent the broken communication between the trunk and the leaves, by the fall of which the scars are produced. Next the apex of a trunk the scars are always arranged with great regularity, but towards the lower part of the stem they become much longer, irregular in form, and are separated by deep furrows; from which it is to be inferred, that, although in these plants no new parts are added, except at the point of the trunk, yet that the parts after being formed do grow both in length and breadth.

Below the scars of the leaves are often (always?) found elliptical or roundish perforations, filled with a powdery matter. These have no obvious analogy in other plants, unless they are to be compared to the perforations in the rhizoma of Nymphæa.

It may be easily understood, that, taking such a structure as is now described for the type of Ferns, the name Acrogens (or point-growers) is well applied to them; and that all the modifications of structure which exist in the small species are mere reductions of developement, or adaptations of the same type to peculiar circumstances.

Their petioles, or *stipes* (*rachis*, W.; *peridroma*, Necker), consist of sinuous strata of indurated, very compact tissue, connected by cellular matter; and the wood of those which have arborescent trunks is formed by the cohesion of the bases of such petioles round a hollow or solid cellular axis. The organs of reproduction are produced from the back or under side of the leaves. In Polypodiaceæ, or what are more commonly called dorsiferous ferns, they originate, either upon the epidermis or from beneath it, in the form of spots, at the junctions, margins, or extremities of the veins. As they increase in growth they assume the appearance of small heaps of granules, which heaps are called *sori*. If examined beneath the microscope, these granules, commonly called *sporangia*, *thecæ*, *capsules*, or *conceptacles*, are found to be little, brittle, compressed bags formed of cellular membrane, partially surrounded by a thickened longitudinal ring (*gyrus*, *annulus*, *gyroma*), which sometimes at the vertex loses itself in the cellularity of the membrane, and at the base tapers into a little stalk. The sporangia burst with elasticity by aid of their ring, and emit minute particles named *spores* or *sporules*, from which new plants are produced: as from seeds, in vegetables of a higher order. Interspersed with the sporangia are often intermixed articulated hairs; and, in those genera in which the sporangia originate beneath the epidermis, the sori, when mature, continue covered with the superincumbent portion of the epidermis, which is then called the *indusium* or *involucrum* (*membranula*, Necker; *glandulæ squamosæ*, Guettard). In Trichomanes and Hymenophyllum, the sporangia are seated within the dilated cup-like extremities of the lobes of the frond, and are attached to the vein which passes through their axis, which is then called their *receptacle.* In Gleicheniaceæ, the sporangia have a transverse complete, instead of a vertical incomplete, ring, and they are nearly destitute of stalks; in others the sori occupy the whole of the under surface of the leaf, which becomes contracted, and wholly alters its appearance: the sporangia have no ring, and the cellular tissue of their membrane is not reticulated, but radiates regularly from the apex.

In these plants it has been in vain endeavoured to discover traces of organs of fecundation. Nevertheless, as it was difficult for sexualists to believe that plants of so large a size were destitute of such organs, it has been considered indispensable that they should be found; and, accordingly, while all seem to agree in considering the sporangia as female organs, a variety of other parts have been dignified by the title of male organs: thus, Micheli and Hedwig found the latter in certain stipitate glands of the leaf; Stæhelin, Hill, and Schmidel, in the elastic ring; Kœlreuter, in the indusium; Gleichen, in the stomates; and Von Martius, in certain membranes enclosing the spiral vessels. None of these opinions are now adopted. M. Bory de St. Vincent contends that impregnation may take place in plants without the agency of pollen, and he affirms that hybrid ferns exist; which, if true, would render it impossible to deny the existence, in this large order, of sexual organs; but where are they? (*Comptes Rendus*, v. 125.)

In Ophioglossaceæ, a remarkable tribe of Ferns, the fertile leaf is rolled up in two lines parallel with its axis or midrib, and at maturity opens regularly by transverse valves along its whole length, emitting a fine powder, which, when magnified, is found to consist of particles of the same nature as the spores found in the sporangia of other ferns; here there are no sporangia, the metamorphosed leaf probably performing their functions. Such is my view of the structure of Ophioglossaceæ; but by other botanists it is described as a dense spike of two-valved capsules, dehiscing transversely.

2. *Equisetaceæ.*

In these plants, which may, I think, be as properly considered the lowest form of flowering plants, the stem is hollow, jointed, and bears a toothed sheath at each joint. The cylinder of the stem is pierced by longitudinal fistulæ, which alternate with furrows on the outside of the stem; there is also a bundle of ringed vessels connected with the fistulæ.

The organs of reproduction are arranged in a cone, consisting of scales bearing on their lower surface an assemblage of cases, called *sporangia*, *thecæ*, *folliculi*, or *involucra*, which dehisce longitudinally inwards. In these sporangia are contained two sorts of granules; the one very minute and lying irregularly among a larger kind, wrapped in two filaments, fixed by their middle, rolled spirally, having either extremity thickened, and uncoiling with elasticity. By Hedwig the apex of the larger granules was supposed to be a stigma, and the thickened ends of the filament anthers, the small granules being the pollen. It is certain that the larger granules, round which the elastic filaments are coiled, are the reproductive particles: and it seems to me that they may be compared to the naked seeds of Coniferæ, the only order to which Equisetaceæ appear to have much resemblance; but Mr. Griffith differs from me upon this point. This excellent observer states that the club-shaped bodies which Hedwig referred to stamens are elaters, and are developed in or on a loose membranous coat, and later than the central body, spore, or seed.

3. *Lycopodiaceæ.*

These are leafy plants with the habit of gigantic mosses. Their leaves and stem have the same structure as those plants, except that the former are sometimes provided with stomates, and the latter with a central bundle of vessels.

Their organs of reproduction are kidney-shaped two-valved cases, called *thecæ*, *sporocarpia*, *conceptacles*, or *capsules*, either 1. filled with minute powder-like granules, which, in consequence of lateral compression, from being spherical, acquire the figure of irregular polygons; or 2. containing three or four roundish fleshy bodies, marked at the apex by a three-legged line, and each of which is at least fifty times larger than the granules contained in the first kind of theca; the latter are said by Brotero to burst with elasticity, an observation which requires verification. The first kind of theca is found in all species of Lycopodiaceæ; the second is only found in a a few. The contents of both are believed to be sporules; but no satisfactory explanation has yet been offered of the cause of their difference in size, and probably also in structure. I would suggest that the powder-like grains are true sporules, and that the large ones are buds or viviparous organs, as has already been stated by Haller and Willdenow. A writer in the *Transactions of the Linnean Society* has figured and described the growth of the larger grains of Lycopodium denticulatum, and he considers that they exhibit the germination of a dicotyledonous plant; but, independently of any mistrust which may attach to the account, it is obvious enough that his own drawings and description represent a mode of germination analogous, not to that of dicotyledons, but rather to that of monocotyledons, and also reducible to the laws which govern the incipient vegetation of a bud.

The powder-like sporules are inflammable, and have been supposed by Haller, Linnæus, and others, to be pollen, while the larger have been considered seeds; and to a part of the surface of the theca the office of stigma has been attributed. The thecæ themselves have been fancied to be male apparatus by Kœlreuter and Gærtner.

4. *Marsileaceæ.*

This very curious little order consists of plants differing from each other so much, that, although consisting of only four genera, it is necessary to subdivide it into two distinct tribes.

The type of Marsileaceæ, properly so called, may be taken from Marsilea itself, of which the most complete account has been given by M. Fabre.

In Marsilea Fabri the fructification consists of a two-valved coriaceous involucre (*sporocarpium*, Endl.), having its valves held together by a central line continuous with the stalk: this involucre seems to be a modified leaf. From the stalk there rises a mucilaginous ring, to which adhere minute ramifications of the spike, terminating in oblong spikes covered with fructification. After a time the mucilaginous ring detaches itself from the stalk at one end, straightens, and carries up with it the spikes of fructification, whose connection with the stalk is then destroyed. The spikes are at first enveloped in a mucous membrane, and are composed of two sorts of bodies closely packed together, and considered by M. Dunal to be ovules and anthers. These bodies are sometimes intermixed, sometimes stationed separately from each other. The so called ovules are little white semitransparent bodies, surrounded by a sort of projecting hood, beyond which a narrow papilla projects: this papilla is always turned towards the anthers. The latter are little flat parallelopipedons, rounded at the two ends; they consist of a membranous sac of great tenuity, in which are found numerous grains of spherical or elliptical pollen. (*Ann. Sc.*, n. s. vii. 227. t. 12, 13.) M. Fabre is represented as having proved experimentally that the latter impregnate the former; and he has traced the ovules from their first impregnation to their completion, and seen and described their germination. (*Id.* ix. 115. t. 13.) It appears that no trace of embryo is discoverable in the ripe seed.

In the second section of this order, to which the name Salvinieæ may be given, and which consists of the genera Salvinia and Azolla, we find at the base of the leaves membranaceous involucres of two sorts, and containing different organs. One kind includes a bunch of cases (*sporangia*, Martius), containing only one grain in Salvinia, and from six to nine in Azolla. The integument of these cases is thin, reticulated, brownish, and does not swell in water like that of true Marsileaceæ: the pedicle which supports them appears, in Salvinia, to communicate laterally with the case. The other involucres, which are supposed to be male organs, have a very complex structure, and have been well observed by Brown. In Salvinia they contain a great number of spherical granules, attached by long pedicles to a central column: these granules are much smaller than the grains; their surface is reticulated in like manner, and they do not burst by the action of water. All the species are floaters, and their leaves are not gyrate when developing, but are more like those of Lycopodiaceæ. Thus far Brongniart; see also Martius, *Ic. Pl. Crypt. Bras.*, for many curious additional observations.

With respect to the nature of these two kinds of grains or granules, it has been thought, as is obvious from the foregoing remarks, that the smaller are males and the larger females; which has been supposed to be proved by the experiments of Savi of Pisa. This observer introduced into different vessels, 1. the granules; 2. the grains; and, 3., the two intermixed. In the first two nothing germinated; in the third the grains floated to the surface and developed themselves perfectly. These observations have, however, been repeated by Duvernoy without the same result. But M. Fabre's observations upon Marsilea seem to leave little doubt about this order having reproductive organs analogous to sexes.

5. *Mosses and Andræaceæ.*

In the structure of these plants neither vessels nor woody tissue are employed; and henceforward those organs disappear from the structure of all the orders to be noticed. Their stem consists of elongated cellular tissue, from which arise leaves composed, in like manner, entirely of cellular tissue without woody tissue; the nerves, as they are called, or, more properly speaking, ribs, which are found in many species, being formed by the approximation of cellules more elongated than those which constitute the principal part of the leaf. The leaves are usually a simple lamina; but in Polytrichum and a few others they are furnished with little plates called lamellæ, running parallel with the leaf, and originating in the upper surface.

At the summit of some of the branches of many species are seated certain organs, which are called male flowers, but the true nature of which is not understood. They are possibly organs of reproduction of a particular kind, for both Mees and Haller are recorded to have seen them produce young plants. Agardh says they have only the form of male organs; and that they really appear to be gemmules. By Hedwig they were called *spermatocystidia;* by others *staminidia* or *antheridia.* They are cylindrical, articulated, clavate, membranous bodies, opening by an irregular perforation at the apex, and discharging a mucous granular fluid. Among them are found slender, pellucid, jointed threads, which are abortive antheridia. Unger and Meyer have found spermatic animalcules, apparently Vibrios, in the antheridia of Sphagnum and Hypnum. (*Comptes Rendus,* vi. 632.)

But, whatever may be the nature of these organs, there is no doubt of the reproductive functions of the contents of what is named the *sporangium, theca,* or *capsule,* which is a hollow urn-like body, containing *sporules:* it is usually elevated on a stalk, named the *seta,* with a bulbous base, surrounded by leaves of a different form from the rest, and distinguished by the name of *perichætial* leaves. If this sporangium be examined in its youngest state, it will be seen to form one of several small sessile ovate bodies (*pistillidia,* Agardh; *prosphyses,* Ehrhart; *adductores,* Hedwig), enveloped in a membrane tapering upwards into a point; when abortive they are called *paraphyses.* In process of time the most central of these bodies swells, and bursts its membranous covering, of which the greatest part is carried upwards on its point, while the seta on which the sporangium is supported lengthens. This part, so carried upwards, is named the *calyptra:* if it is torn away equally from its base, so as to hang regularly over the sporangium, it is said to be *mitriform;* but if it is ruptured on one side by the expansion of the sporangium, which is more frequently the case, it is denominated *dimidiate.* When the calyptra has fallen off or is removed, the sporangium is seen to be closed by a lid terminating in a beak or rostrum: this lid is the *operculum,* and is either deciduous or persistent. If the interior of the sporangium be now investigated, it will be found that the centre is occupied by an axis, called the *columella;* and that the space between the columella and the sides of the sporangium is filled with sporules. The brim of the sporangium is furnished with an elastic external ring, or *annulus,* and an interior apparatus, called the *peristomium:* this is formed of two distinct membranes, one of which originates in the outer coating of the sporangium, the other in the inner coat; hence they are named the outer and inner peristomia. The nature of the peristomium is practically determined at the period of the maturity of the sporangium. At this time both membranes are occasionally obliterated; but this is an unfrequent occurrence: sometimes one membrane only remains, either divided into divisions, called teeth, which are always some multiple of four, varying from that number as high as eighty, or stretching across the orifice of the theca, which is closed up by it; this is sometimes named the *epiphragma* or *tympanum.* Most frequently both membranes are present, divided into teeth, from differences in the number or cohesion of which the generic characters of mosses are in a great measure formed. For further information upon the peristomium, see Brown's remarks upon Lyellia, in the 12th volume of the *Linnean Transactions.*

M. Endlicher considers that the sporangium is formed by the adhesion of an external and internal series of organs; and he calls *sporangidium* the inner, to which the peristomium belongs. (*Genera Plantarum,* 46.)

The interior of the sporangium is commonly unilocular; but in some species, especially of Polytrichum, it is separated into several cells by dissepiments originating with the columella.

If at the base of the sporangium there is a dilatation or swelling on one side, this is called a *struma;* if it is regularly lengthened downwards, as in most of the Splachnums, such an elongation is called an *apophysis.*

In Andræaceæ the sporangium is not an urn-like case, but splits into four valves, cohering by the operculum and base.

The spores have no adhesion either to the sides of the sporangium or to the columella, but appear to be formed much in the same way as pollen. When they germinate they produce capillary, articulated, green, branched threads, resembling Confervæ; and the leaves eventually appear from the axils of such branches.

From the foregoing description, it will be apparent that the organs of reproduction of Mosses cannot be compared strictly to the parts of fertilisation of perfect plants. I must not, however, omit the opinion of other botanists upon this subject. The office of males has been supposed by Micheli to be performed by the paraphyses; by Linnæus and Dillenius, by the sporangia; by Palisot de Beauvois, by the sporules; by Hill, by the peristomium; by Kœlreuter, by the calyptra; by Gærtner, by the operculum; and, finally, Hedwig has supposed the males to be the antheridia. The female organs were thought by Dillenius and Linnæus to be assemblages of antheridia; by Micheli and Hedwig, the young sporangia; and, by Palisot de Beauvois, the columella.

For some suggestions as to the analogy that is borne between the organs of Mosses and those of other plants, see MORPHOLOGY hereafter, and Endlicher's *Genera Plantarum.*

6. *Jungermanniaceæ and Hepaticæ.*

These differ remarkably from each other in the modifications of their organs of reproduction, while they have a striking resemblance in their vegetation. This latter, which bears the name of *frond* or *thallus*, is either a leafy branched tuft, as in Mosses, with the cellular tissue particularly large, and the leaves frequently furnished with lobes, and appendages at the base, called *stipulæ* or *amphigastria;* or it is a flat lobed mass of green vegetable matter lying upon the ground.

In Jungermannia, that part which is most obviously connected with the reproduction of the plant, and which bears an indisputable analogy to the theca of Mosses, is a valvular brown case, called the capsule or conceptacle (*sporangium* or *sporocarpium*), elevated upon a white cellular tender seta, and originating in a hollow sheath or perichætium arising among the leaves. This conceptacle contains a number of loose spiral fibres (*elaters*), enclosed in membranous cases, among which sporules lie intermixed: when fully ripe, the membranous case usually disappears, the spiral fibres, which are powerfully hygrometric, uncurl, and the sporules are dispersed. When young, the conceptacle is enclosed in a membranous bag (*epigonium*), which it ruptures when it elongates, but which it does not carry upwards upon its point, as Mosses carry their calyptra. This part, nevertheless, bears the latter name.

Besides the conceptacles of Jungermannia, there are two other parts which are thought to be also intended for the purpose of reproduction: of these, one consists of spherical bodies, scattered over the surface of some parts of the frond, and containing a granular substance; the other is a hollow pouch, formed out of the two coats of a flat frond, and producing from its inside, which is the centre of the frond, numerous granulated round bodies which are discharged through the funnel-shaped apex of the pouch.

There are also other bodies situated in the axillæ of the perichætial leaves, called anthers (*spermatocystidia*, *antheridia*, *pollinaria*, *staminidia*), which "are externally composed of an extremely thin, pellucid, diaphanous membrane, within they are filled with a fluid, and mixed with a very minute granulated substance, generally of an olivaceous or greyish colour: this, when the anther has arrived at a state of maturity, escapes through an irregularly shaped opening, which bursts at the extremity." Von Martius suspects these to be analogous to the sporangia of Azolla.

In Monoclea and Targionia organs nearly analogous to those of Jungermannia are formed for reproduction. In Targionia the antheridia are represented by M. Montagne as being embedded in disks very like the shields of Lichens. (*Ann. Sc.*, n. s. ix. 100.)

In Marchantia the frond is a lobed flat green substance, not dividing into leaves and stems, but lying horizontally upon the ground, and emitting roots from its under surface. The organs of reproduction consist, firstly, of a stalked fungus-like receptacle, carrying on its apex a calyptra, and bearing sporangia on its under side; secondly, of a stalked receptacle, plane on the upper surface, with oblong bodies embedded vertically in the disk, and called anthers; thirdly, "of little open cups (*cystulæ*), sessile on the upper surface of the fronds, and containing minute green bodies (*gemmæ*), which have the power of producing new plants." The first kind is usually considered a female flower, its spores being intermixed with elaters; the second male, and the third viviparous, apparatus. In the opinion of many modern botanists, the granules of both the first two are spores: about the function of the last there is no difference of opinion. Mirbel considers the first two to be male and female; but, whatever their functions may be, in structure there is but little analogy between them and the organs of more perfect plants. Meyen describes spermatic animalcules, resembling the genus Vibrio, as occupying the interior of each grain of the supposed pollen in Marchantia polymorpha. (*Comptes Rendus*, vi. 583.)

In Anthoceros, while the vegetation is the same as in Marchantia, the organs of reproduction are very different. They consist of a subulate column, issuing from a perichætium perpendicular to the frond, and dividing half way into two valves, which discover, upon opening, a subulate columella, to which sporules are attached without any elaters. There are also cystulæ upon the frond, in which are enclosed pedicellate reticulated bodies, called anthers.

Sphærocarpus consists of a delicate roundish frond, on the surface of which are clustered several cystulæ, each of which contains a transparent spherule filled with sporules.

In Riccia the spherules are not surrounded by cystulæ, but immersed in the substance of the frond.

7. *Lichens.*

These have a lobed frond or *thallus* (or *blastema*), the inner substance of which consists wholly of reproductive matter, that breaks through the upper surface in certain forms which have been called fructification. These forms are twofold; firstly, *shields* (*scutella* or *apothecia*), which are little coloured cups or lines with a hard disk, surrounded by a rim, and containing *asci*, or tubes filled with sporules; and, secondly, *soredia*, which are heaps of pulverulent bodies scattered over the surface of the thallus. The nomenclature of the parts of Lichens has been excessively extended beyond all necessity: it is, however, desirable that it should be understood by those who wish to read the systematic writers upon the subject.

1. *Apothecia*, are shields of any kind.
2. *Perithecium*, is the part in which the asci are immersed.
3. *Hypothecium*; the substance that surrounds, or overlies the perithecium, as in Cladonia.
4. *Scutellum*, is a shield with an elevated rim, formed by the thallus. *Orbilla*, is the scutellum of Usnea.
5. *Pelta*, is a flat shield without any elevated rim, as in the genus Peltidea.
6. *Tuberculum*, or *Cephalodium*, is a convex shield without an elevated rim.
7. *Trica*, or *Gyroma*, is a shield, the surface of which is covered with sinuous concentric furrows.
8. *Lirella*, is a linear shield, such as is found in Opegrapha, with a channel along its middle.
9. *Patellula*; an orbicular sessile shield, surrounded by a rim which is part of itself, and not a production of the thallus, as in Lecidea. *D. C.*
10. *Globulus*; a round deciduous shield, formed of the thallus, and leaving a hollow when it falls off, as in Isidium. *D. C.*
11. *Pilidium*; an orbicular hemispherical shield, the outside of which changes to powder, as in Calycium. *D. C.*
12. *Podetia*; the stalk-like elongations of the thallus, which support the fructification in Cenomyce.
13. *Scypha* (*oplarium*, Neck.), is a cup-like dilatation of the podetium, bearing shields on its margin.
14. *Soredia* (*globuli*, *glomeruli*), are heaps of powdery bodies lying upon any part of the surface of the thallus. The bodies of which the soredia are composed are called *conidia* by Link, and *propagula* by others.
15. *Cystula*, or *Cistella*; a round closed apothecium, filled with sporules, adhering to filaments which are arranged like rays around a common centre, as in Sphærophoron.
16. *Pulvinuli*, are spongy excrescence-like bodies, sometimes

rising from the thallus, and often resembling minute trees, as in Parmelia glomulifera. *Greville.*

17. *Cyphellæ*, are pale tubercle-like spots on the *under* surface of the thallus, as in Sticta. *Grev.*
18. *Lacunæ*, are small hollows or pits on the *upper* surface of the thallus. *Grev.*
19. *Nucleus proligerus*, is a distinct cartilaginous body, coming out entire from the apothecia, and containing the sporules. *Grev.*
20. *Lamina proligera*, is a distinct body containing the sporules, separating from the apothecia, often very convex and variable in form, and mostly dissolving into a gelatinous mass. *Grev.*
21. *Fibrillæ*, are the roots.
22. *Excipulus*, is that part of the thallus which forms a rim and base to the shields.
23. *Nucleus*, is the disk of the shield which contains the sporules and their cases.
24. *Asci*, are tubes, in which the sporules are contained while in the nucleus.
25. *Thallodes*, is an adjective used to express an origin from the thallus: thus, *margo thallodes* signifies a rim formed by the thallus, *excipulus thallodes* a cup formed by the thallus.
26. *Lorulum*, is used by Acharius to express a filamentous branched thallus.
27. *Crusta*, is a brittle crustaceous thallus.
28. *Gongyli*, are the granules contained in the shields, and have been thought to be the spores by which Lichens are propagated: but this is doubted by Agardh.

8. *Algaceæ.*

These, with Fungi, constitute the lowest order of vegetable developement: they vary from mere microscopic objects to a large size, and are composed of cellular tissue in various degrees of combination; some are even apparently animated, and thus form a link between the two great kingdoms of organised matter. Their spores are either scattered through the general mass of each plant, or collected in certain places which are more swollen than the rest of the stem, and sometimes resemble the pericarpia of perfect plants.

Nothing which can be compared to male organs has yet been found in Algaceæ; but it is not impossible that matter, possessing the properties of pollen, may be mixed up with the spores, in the inside of the tubes or other bodies in which they are developed. The mode of propagation in Algaceæ is extremely variable, but apparently always takes place by the formation of spores, either within the ordinary cells of the plant, or within sporangia of one kind or other. The Zygnemata have the curious attribute of forming their spores by the copulation of two contiguous branches.

The terms used in speaking of the parts of these plants are the following: —

1. *Gongylus;* a round hard body, which falls off the mother plant, and produces a new individual: this is found in Fuci. *W.*
2. *Thallus;* the plant itself.
3. *Apothecia;* the cases in which the organs of reproduction are contained.
4. *Peridiolum*, Fr.; the membrane by which the sporules are immediately covered.
5. *Granula;* large sporules, contained in the centre of many Algaceæ; as in Gloionema of Greville. *Crypt. Fl.* 6. 30.
6. *Pseudoperithecium;*
7. *Pseudohymenium;*
8. *Pseudoperidium;* } terms used by Fries to express such coverings of sporidia as resemble in figure the parts named perithecium, hymenium, and peridium in other plants: see those terms.
9. *Sporidia;* granules which resemble sporules, but which are of a doubtful nature. It is in this sense that Fries declares that he uses the word: vide *Plant. homonom.* p. 294. They are also called *Sporæ.*
10. *Phycomater*, Fries; the gelatine in which the sporules of Byssaceæ first vegetate.
11. *Vesiculæ;* inflations of the thallus, filled with air, by means of which the plants are enabled to float.

12. *Hypha*, Willd.; the filamentous, fleshy, watery thallus of Byssaceæ.
13. *Sporangia;* any kind of case not obviously a joint of the plant, within which spores are generated.
14. *Coniocysta;* tubercle-like closed apothecia, containing a mass of sporules; the same as sporangium.

9. *Fungaceæ.*

The structure of these plants is yet more simple than that of Algaceæ, consisting of little besides cellular tissue, among which spores are generated. Some, of the lowest degree of developement, are composed only of a few cellules, of which one is larger than the rest, and contains the spores; others are more highly compounded, consisting of myriads of cellules, with the sporules lying in cases, or *asci*.

Sexes have been generally denied to Fungaceæ: but M. Leveillé has shown that, in the Agaric and some other high forms of the order, there are two sorts of organs; the one prominent cells containing a highly attenuated form of matter, and the other undoubtedly spores; and that these two kinds of organs are intermingled with each other. There is, however, as yet, no *proof* that the prominent cells are male organs.

Corda has shown that spiral-threaded cells, analogous to elaters, exist in the genus Trichia.

It is exclusively among these plants that we meet with cases of parasitism upon living animal bodies. The silkworm, and hymenopterous insects, are destroyed by the action of certain species of Botrytis in the one case, and Sphæria in the other, which attack them while alive.

Notwithstanding the extreme simplicity of these plants, writers upon Fungi have contrived to multiply the terms relating to them in a remarkable manner. The following are all with which I am acquainted: —

1. The *Pileus*, or *Cap*, is the uppermost part of the plant of an Agaricus, and resembles an umbrella in form.
2. The *Stipes*, is the stalk that supports the pileus.
3. The *Volva*, or *Wrapper*, is the involucrum-like base of the

stipes of Agaricus. It originally was a bag enveloping the whole plant, and was left at the foot of the stipes when the plant elongated and burst through it.

4. The *Velum*, or *Veil*, is a horizontal membrane, connecting the margin of the pileus with the stipes: when it is adnate with the surface of the pileus, it is a *velum universale;* when it extends only from the margin of the pileus to the stipes, it is a *velum partiale.*
5. The *Annulus*, is that part of the veil which remains next the stipes, which it surrounds like a loose collar.
6. *Cortina*, is a name given to a portion of the velum which adheres to the margin of the pileus in fragments.
7. The *Hymenium*, is the part in which the sporules immediately lie; in Agaricus, it consists of parallel plates, called *lamellæ*, or *gills.* These are *adnate* with the stipes, when the end next it coheres with it: when they are adnate, and at the same time do not terminate abruptly at the stipes, but are carried down it more or less, they are *decurrent;* if they do not adhere to the stipes, they are said to be *free.*
8. *Stroma*, is a fleshy body to which flocci are attached; as in Isaria and Cephalotrichum.
9. *Flocci*, are woolly filaments found mixed with sporules in the inside of many Gastromyci. The same name is also applied to the external filaments of Byssaceæ.
10. *Orbiculus*, is a round flat hymenium contained within the peridium of some fungi; as Nidularia. *W.*
11. *Nucleus*, is the central part of a perithecium.
12. *Sporangium*, is the external case of Lycoperdon and its allies.
13. *Sporangiola*, are cases containing sporidia.
14. *Perithecium*, is a term used to express the part which contains the reproductive organs of Sphæria and its coordinates.
15. *Peridium*, is also a kind of covering of sporidia; *peridiolum* is its diminutive.
16. *Ostiolum*, is the orifice of the perithecium of Sphæria.
17. *Spherula*, is a globose peridium, with a central opening

through which sporidia are emitted, mixed with a gelatinous pulp.

18. *Capillitium*, is a kind of purse or net, in which the sporules of some Fungi are retained; as in Trichia. *W.*
19. *Trichidium*, or *Pecten*, is a tender, simple, or sometimes branched hair, which supports the sporules of some Fungi; as Geastrum. *W.*
20. *Asci*, are the tubes in which the sporidia are placed; *ascelli* or *thecæ* are the same thing.
21. *Sporidia*, are the immediate covering of sporules. *Sporidiola*, are *sporules.*
22. *Thallus*, or *Thalamus*, is the bed of fibres from which many Fungi arise.
23. *Mycelia*, are the rudiments of Fungi, or the matter from which Fungi are produced.
24. *Cystidia*, are the projecting cells, or supposed male organs, of Agarics, &c.
25. *Basidia*, are the cells on the apex of which the spores of such plants are formed.

BOOK II.

PHYSIOLOGY; OR, PLANTS CONSIDERED IN A STATE OF ACTION.

GENERAL CONSIDERATIONS.

We have thus far considered plants as inert bodies, having certain modifications of structure, and formed upon a plan, the simplicity and uniformity of which is among the most beautiful proofs of the boundless power and skill of the Deity.

Our next business is to enquire into the nature of their vital actions, and to consider those phenomena in which the analogy that undoubtedly exists between plants and animals is most striking; in a word, to make ourselves acquainted with what is known of the laws of vegetable life.

In explaining these things, it is not my purpose to notice all the different speculations that ingenious men have from time to time brought forward: for this would be incompatible with the plan of my work, and would be far more curious than useful. On the contrary, I propose, in the first place, to give a summary exposition of the principal phenomena of vegetation, and then to support the statement by a detailed account of the more important proofs of all disputed points.

In this I have been materially assisted by the *Physiologie Végétale* of De Candolle, a work of which it is difficult to speak in terms of sufficient eulogy, but which I feel justified in describing as the most important production on the subject of Vegetable Physiology, since the appearance of the *Physique des Arbres* of Duhamel.

I. If we place a seed (that of an apple, for instance) in earth at the temperature of 32° Fahr., it will remain inactive till it finally decays. But if it is placed in moist earth above the temperature of 32°, and screened from the action of light, its integument gradually imbibes moisture and swells; the tissue is softened, and acquires the capability of stretching; the water is decomposed, and a part of its oxygen, combining with the carbon of the seed, forms carbonic acid, which is expelled; nutritious food for the young parts is prepared by the conversion of starch into sugar; and the vital action of the embryo commences. It lengthens downwards by the radicle, and upwards by the cotyledons; the former penetrating the soil, the latter elevating themselves above it, acquiring a green colour by the decomposition of the carbonic acid they absorb from the earth and atmosphere, and unfolding in the form of two opposite roundish leaves. This is the first stage of vegetation: the young plant consists of little more than cellular tissue; only an imperfect developement of vascular and fibrous tissue being discoverable, in the form of a sort of cylinder, lying just in the centre. The part within the cylinder, at its upper end, is now the pith, without it the bark; while the cylinder itself is the preparation for the medullary sheath, and consists of vertical tubes passing through and separated by cellular tissue.

The young root is now lengthening at its point, and absorbing from the earth its nutriment, which passes up to the summit of the plant by the cellular substance, and is, in part, impelled into the cotyledons, where it is aërated and evaporated, but chiefly urged upwards against the growing point or plumule.

II. Forced onwards by the current of sap, which is continually impelled upwards from the root, the plumule next ascends in the form of a little twig, at the same time sending downwards, in the centre of the radicle, the earliest portion of wood that is deposited, and compelling the root to emit little ramifications; and simultaneously the process of lignification is going on in all the tissue, by the deposit of a peculiar secretion in layers within the cells and tubes.

Previously to the elongation of the plumule, its point has acquired the rudimentary state of a leaf: this latter continues to develope as the plumule elongates, until, when the first internode of the latter ceases to lengthen, the leaf has actually arrived at its complete formation. When fully grown it repeats in a much more perfect manner the functions previously performed by the cotyledons: it aërates the sap that it receives, and returns the superfluous portion of it downwards through the bark to the root; it also sends tubular tissue down between the medullary sheath and the bark, thus forming the first ligneous stratum, a part of which is incorporated with the bark, the remainder forming wood.

During these operations, while the plumule is ascending, its leaf forming and acting, and the woody matter created by it descending, the cellular tissue of the stem is forming, and expanding horizontally, to make room for the new matter forced into it; so that developement is going on simultaneously both in a horizontal and perpendicular direction. This process may not inaptly be compared to that of weaving, the warp being the perpendicular, and the weft the horizontal, formation. In order to enable the leaf to perform its functions of aëration completely, it is traversed by veins originating in the medullary sheath, and has delicate pores (*stomates*), which communicate with a highly complex pneumatic system extending to almost every part of the plant.

Simultaneously with the descent of woody matter downwards from the leaf, the emission of young roots, and their increase by addition to the cellular substance of their points, take place. They thus are made to bear something like a definite proportion to the leaves they have to support, and with which they must of necessity be in direct communication.

After the production of its first leaf by the plumule, others successively appear in a spiral direction around the axis at its growing point, all constructed alike, connected with the stem or axis in the same manner, and performing precisely the same functions as have been just described. At last the axis ceases to lengthen; the old leaves gradually fall off; the new leaves, instead of expanding after their formation, retain their rudimentary condition, harden, and fold over one another, so as to be a protection to the delicate point of growth; or, in other words, become the scales of a bud. We have now a shoot with a woody axis, and a distinct pith and bark; and of a more or less conical figure. At the axil of every leaf a new growing point had been generated during the growth of the axis; so that the shoot, when deprived of its leaves, is covered from end to end with little, symmetrically arranged, projecting bodies, which are the buds.

The cause of the figure of the perfect shoot being conical is, that, as the wood originates in the base of the leaves, the lower end of the shoot, which has the greatest number of strata, because it has the greatest number of leaves above it, will be the thickest; and the upper end, which has had the fewest leaves to distend it by their deposit, will have the least diameter. Thus that part of the stem which has two leaves above it will have wood formed by two successive deposits; that which has nine leaves above it will have wood formed by nine successive deposits; and so on: while the growing point, as it can have no deposit of matter from above, will have no wood, the extremity being merely covered by the rudiments of leaves hereafter to be developed.

If at this time a cross section be examined, it will be found that the interior is no longer imperfectly divided into two portions, namely, pith and skin, as it was when first examined in the same way, but that it has distinctly two internal, perfect, concentric lines, the outer indicating a separation of the bark from the wood; and the inner, a separation of the wood from the pith: the latter, too, which in the first observation was fleshy, and saturated with humidity, is become distinctly cellular, and altogether or nearly dry.

III. With the spring of the second year, and the return of warm weather, vegetation recommences.

The uppermost, and perhaps some other, buds, which were formed the previous year, gradually unfold, and pump up sap from the stock remaining in store about them; the place of the sap so removed is instantly supplied by that which is next it; an impulse is thus given to the fluids from the summit to the roots; fresh extension and fresh fibrils are given to the roots; new sap is absorbed from the earth, and sent upwards through the wood of last year; and the phenomenon called the flow of the sap is fully completed, to continue with greater or less velocity till the return of winter. The growing point lengthens upwards, forming leaves and buds in the same way as the parent shoot: a horizontal increase of the whole of the cellular system of the stem takes place, and each bud sends down ligneous matter within the bark and above the wood of the shoot from which it sprang; thus forming on the one hand a new layer of wood, and on the other a fresh deposit of liber.

In order to facilitate this last operation, the old bark and wood are separated in the spring by the exudation from both of them of the glutinous slimy substance called cambium; which appears to be expressly intended, in the first instance, to facilitate the descent of the subcortical tissue from the growing buds; and, in the second place, to assist in generating the cellular tissue by which the horizontal dilatation of the axis is caused, and which maintains a communication between the bark and the centre of the stem. This communication has, by the second year, become sufficiently developed to be readily discovered, and is effected by the medullary rays spoken of in the last book. It will be remembered that there was a time when that which is now bark constituted a homogeneous body with the pith; and that it was after the leaves began to come into action that the separation which now exists between the bark and pith took place. At the time when the latter were indissolubly united they both consisted of cellular tissue, with a few spiral vessels upon the line indicative of future separation. When a deposit of wood was formed from above between them they were not wholly divided the one from the other, but the deposit was effected in such a way as to leave a communication by means of cellular tissue between the bark and the pith; and, as this formation, or medullary ray, is at all times coetaneous with that of the wood, the communication so effected between the pith and bark is quite as perfect at the end of any number of years as it was at the beginning of the first; and so it continues to the end of the growth of the plant.

The sap which is drawn from the earth into circulation by the unfolding leaves is exposed, as in the previous year, to the effect of air and light; is then returned through the petiole to the stem, and sent downwards through the bark, to be from it either conveyed to the root, or distributed horizontally by the medullary rays to the centre of the stem.

At the end of the year the same phenomena occur as took place the first season: wood is gradually deposited by slower degrees, whence the last portion is denser than the first, and gives rise to the appearance called the annual zones: the new shoot or shoots are prepared for winter, and are again elongated cones, and the original stem has acquired an increase in diameter proportioned to the quantity of new shoots which it produced, new shoots being to it now, what young leaves were to it before.

IV. The third year all that took place the year before is repeated: more roots appear; sap is again absorbed by the unfolding leaves; and its loss is made good by new fluids introduced by the roots and transmitted through the alburnum or wood of the year before; new wood and liber are deposited by matter sent downwards by the buds; cambium is exuded; the horizontal developement of cellular tissue is repeated, but more extensively; wood towards the end of the year is formed more slowly, and has a more compact character; and another ring appears indicative of this year's increase.

In precisely the same manner as in the second and third years of its existence will the plant continue to vegetate, till the period of its decay, each successive year being a repetition of the phenomena of that which preceded it.

V. After a certain number of years the tree arrives at the age of puberty: the period at which this occurs is very uncertain, depending in some measure upon adventitious circumstances, but more upon the idiosyncrasy, or peculiar constitution, of the individual. About the time when this alteration of habit is induced, by the influence of which the sap or blood of the plant is to be partially directed from its former courses into channels in which its force is to be applied to the production of new individuals rather than to the extension of itself; about this time it will be remarked that certain of the young branches do not lengthen, as had been heretofore the wont of others, but assume a short stunted appearance, probably not growing two inches in the time which had been previously sufficient to produce twenty inches of increase. Of these little stunted branches, called *spurs*, the terminal bud acquires a swollen appearance, and at length, instead of giving birth to a new shoot, produces from its bosom a cluster of twigs in the form of pedicels, each terminated by a bud, the leaves of which are modified for the purposes of reproduction, grow firmly to each other, assume peculiar forms and colours, and form a *flower*, which had been enwrapped and protected from injury during the previous winter by several layers of imperfect leaves, now brought forth as bracts. Sap is impelled into the calyx through the pedicel by gentle degrees, is taken up by it, and exposed by the surface of its tube and segments to air and light; but, having very imperfect means of returning, all that cannot be consumed by the calyx is forced onwards into the circulation of the petals, stamens, and pistil. The petals unfold themselves of a dazzling white tinged with pink, and expose the stamens; at the same time the disk changes into a saccharine substance, which is supposed to nourish the stamens and pistil, and give them energy to perform their functions.

At a fitting time, the stigmatic surface of the pistil being ready to receive the pollen, the latter is injected upon it from the anthers, which have remained near for that particular purpose. When the pollen touches the stigma, the grains adhere by means of its viscid surface, emitting a delicate membranous tube, which pierces into the stigmatic tissue, lengthens there, and conveys the matter contained in the pollen towards the ovules, which the tube finally enters by means of their foramen.

This has no sooner occurred than the petals and stamens fade and fall away, their ephemeral but important functions being accomplished. The sap which is afterwards impelled through the peduncle can only be disposed of to the calyx and ovary, where it lodges: these two swell and form a young fruit, which continues to grow as long as any new matter of growth is supplied from the parent plant. At this time the surface of the fruit performs the functions of leaves in exposing the juice to light and air; at a subsequent period it ceases to decompose carbonic acid, gains oxygen, loses its green colour, assumes the rich ruddy glow of maturity; and the peduncle, no longer a passage for fluids, dries up and becomes unequal to supporting the fruit, which at last falls to the earth. Here, if not destroyed by animals, it lies and decays: in the succeeding spring its seeds are stimulated into life, strike root in the mass of decayed matter which surrounds them, and spring forth as new plants to undergo all the vicissitudes of their parent.

Such are the progressive phenomena in the vegetation, not only of the apple, but of all trees which are natives of northern climates, and of a large part of the herbage of the same countries, modified, of course, by peculiarities of structure and constitution; as in annual and herbaceous plants, and in those the leaves of which are opposite and not alternate: but all the more essential circumstances of their growth are the same as those of the apple tree.

If we reflect upon these phenomena, our minds can scarcely fail to be deeply impressed with admiration at the perfect simplicity and, at the same time, faultless skill, with which all the machinery is contrived upon which vegetable life depends. A few forms of tissue, interwoven horizontally and perpendicularly, constitute a stem; the developement, by the first shoot that the seed produces, of buds which grow upon the same plan as the first shoot itself, and a constant repetition of the same formation, cause an increase in the length and breadth of the plant; an expansion of the bark into a leaf, within which ramify veins proceeding from the seat of nutritive matter in the new shoot, with a provision of air-passages in its substance, and of pores on its surface, enables the crude fluid sent from the root to be elaborated and digested until it becomes the peculiar secretion of the species; the contraction of a branch and its leaves forms a flower; the disintegration of the internal tissue of a petal forms pollen; the folding inwards of a leaf is sufficient to constitute a pistil; and, finally, the gorging of the pistil with fluid which it cannot part with causes the production of a fruit.

In hot latitudes there exists another race of trees, of which Palms are the representatives; and in the north there are many herbs, in which growth, by addition to the outside, is wholly departed from, the reverse taking place; that is to say, their diameter increasing by addition to the inside. As the seeds of such plants are formed with only one cotyledon, they are called monocotyledonous; and their growth being from the inside, they are also named endogens. In these plants the functions of the leaves, flowers, and fruit are in nowise different from those of the apple; their peculiarity consisting only in the mode of forming their stems. When a monocotyledonous seed has vegetated, it usually does not disentangle its cotyledon from the testa, but simply protrudes the collum and the radicle; the cotyledon swelling, and remaining firmly encased in the seminal integuments. The radicle shoots downwards to become root; and a leaf is emitted from the side of the collum. This first leaf is succeeded by another half-facing it, and arising from its axil; the second produces a third half-facing it, and arising also from its axil; and, in this manner, the spiral production of leaves continues, until the plant, if caulescent, is ready to produce its stem. Up to this period, no stem having been formed, it has necessarily happened that the bases of the leaves hitherto produced have been all upon nearly the same plane: and, as each has been produced from the bosom of the other without any such intervening space as occurs in dicotyledonous plants, it would be impossible for the matter of wood, if any were formed, to be sent downwards around the circumference of the plant; it would, on the contrary, have been necessarily deposited in the centre. In point of fact, however, no deposit of wood like that of dicotyledons takes place, either now or hereafter. The union of the bases of the leaves has formed a fleshy stock, cormus, or *plate*, which, if examined, will be found to consist of a mass of cellular tissue, traversed by perpendicular and horizontal bundles of vascular and woody tissue, taking their origin in the veins of the leaves, of which they are manifest prolongations downwards; and there is no trace of separable bark, medullary rays, or central pith: the whole body being a mass of pith, woody and vascular tissue, mixed together. To understand this formation yet more clearly, consider for a moment the internal structure of the petiole of a dicotyledon: it is composed of a bundle or bundles of vascular tissue encased in pleurenchyma, surrounded on all sides with pith, or, which is the same thing, parenchyma. Now suppose a number of these petioles to be separated from their blades, and to be tied in a bunch parallel with each other, and, by lateral pressure, to be squeezed so closely together that their surfaces touch each other accurately, except at the circumference of the bunch; if a transverse section of these be made, it will exhibit the same mixture of bundles of woody tissue and parenchyma, and the same absence of distinction between pith, wood, and bark, which has been noticed in the cormus, or first plate, of monocotyledons.

As soon as the plate has arrived at the necessary diameter, it begins to lengthen upwards, leaving at its base those leaves which were before at its circumference, and carrying upwards with it such as occupied its centre; at the same time, new leaves continue to be generated at the centre, or, as it must now be called, at the apex of the shoot.

As fresh leaves are developed, they thrust aside to the circumference those which preceded them, and a stem is by degrees produced. Since it has not been formed by additions made to its circumference by each successive leaf, it is not conical, as in dicotyledons; but, on the contrary, as its increase has been at the centre, which has no power to extend its limits, being confined by the circumference which, when once formed, does not afterwards materially alter in dimensions, it is, of necessity, cylindrical: and this is one of the marks by which a monocotyledon is often to be known, in the absence of other evidence. The centre, being but little acted upon by lateral pressure, remains loose in texture, and, until it becomes very old, does not vary much from the density acquired by it shortly after its formation; but the tissue of the circumference being continually jammed together by the pressure outwards of the new matter formed in the centre, in course of time becomes a solid mass of woody matter, the cellular tissue once intermingled with it being almost obliterated, and appearing among the bundles it formerly surrounded, like the interstices around the minute pebbles of a mosaic gem.

Such is the mode of growth of Palms, and of a great proportion of arborescent monocotyledons. But there are others in which this is in some measure departed from. In the common Asparagus the shoots produce a number of lateral buds, which all develope and influence its form, as the buds of dicotyledons; so that the cylindrical figure of monocotyledons is exchanged for the conical: its internal structure is strictly endogenous. In Grasses a similar conical figure prevails, and for the same reason; but they have this additional peculiarity, that their stem, in consequence of the great rapidity of its growth, is fistular, with transvere phragmata at its nodes. The phragmata are formed by the crossing of woody bundles from one side of a stem to the other; and are, perhaps, contrivances to enable the thin cylinder of the stem to resist pressure from without inwards.

In such herbaceous plants as Colchicum, the stem, after a time, is a small tuber with two buds; one at the apex, which becomes the flowering stem and leaves; the other at the base, directed downwards at an obtuse angle. Such a tuber is multiplied by the latter bud, which pushes forward obliquely, and turning upwards, throws up a new flowering stem in the autumn; the base of the flowering stem thickens, enlarges, and assumes the appearance of a new cormus; in the spring, leaves sprout forth, and elaborate matter enough to fill the cells of the new cormus with fæcula, and to organise another oblique bud at the base, and then the growth of a new individual is accomplished. In the mean while, the original cormus is exhausted of all its organisable contents, which are consumed in the support of the young cormus produced from its base; and, by the time that the growth of the latter is completed, the mother is shrivelled up, and dies. It is easy to conceive many modifications of this.

Upon one or other of the two plans now explained are all flowering plants developed; but in flowerless plants it is different. In arborescent Ferns the stem consists of a cylinder of hard sinuous plates, connected by parenchyma, and surrounding an axis, hollow, or filled up with solid matter. It would seem, in these plants, as if the stem consisted of a mere adhesion of the petioles of the leaves in a single row; and that the stem simply lengthens at the point, without transmitting woody matter downwards. Some valuable observations upon this point have been made by Mohl, who has, however, been able only to investigate the anatomical condition of Tree Fern stems, without studying their mode of growth. Lycopodiaceæ equally increase by simple addition to the point; and, as this seems also to be the plan upon which developement takes place in other cryptogamic plants, I have proposed the term Acrogens, to distinguish the latter from Exogens and Endogens.

When leaves are no longer formed, but growth takes place by an irregular expansion of cellular tissue in various directions, the preceding rules are departed from, and nothing being left of the vegetable fabric except the horizontal order of growth, a stem ceases to appear, and a plant becomes an unsymmetrical body, either consisting of solid masses increasing in all directions, or of filamentous matter multiplying itself by internal septation at the elongating apex.

CHAPTER I.

OF THE CHEMICAL CONSTITUTION OF THE ELEMENTARY ORGANS.

The tissue of plants, as it is first generated, and before it is incrusted with the peculiar secretions formed by the leaves, consists exclusively of oxygen, hydrogen, and carbon: and it is probable that none of the kinds of tissue differ originally in their proportions of these three principles; for the microscope does not show a difference in the action of chemical agents upon them.

I mention this because Mr. Rigg has arrived at a different conclusion, the accuracy of which has been insisted upon by the Rev. J. B. Reade, in a paper printed in *Taylor's Magazine* (Nov. 1837). It must be, however, apparent to any person conversant with vegetable anatomy, that such a separation of tissue as in this case is supposed to have been obtained is physically impossible, and, consequently, the results given are fallacious.

The subject has been subsequently taken up by Schleiden and Payen, whose experiments, made independently of each other, and in entirely different ways, both lead to the conclusion that the original tissue of plants is in all cases of the same chemical constitution, or nearly so, but that the sedimentary deposit which is formed inside each sac of tissue is of some other chemical nature; the lignine of chemists is therefore composed of two or more different substances, viz. the primitive tissue and its subsequent incrustations. As this subject is important with reference to many phenomena in vegetable physiology, I give at some length the results of both Schleiden and Payen.

The former makes a statement in *Wiegman's Archives* to the following effect: —

" In the manuals which treat of organic chemistry, we generally find woody fibre treated of as a proximate element amongst the indifferent vegetable substances, along with starch, gum, sugar, &c. It is only lately that Reade has endeavoured to earn the merit of analysing the different forms of organised vegetable substances when separated, but I doubt whether any thing available for science has resulted therefrom. I will, however, in no wise intimate that Mr. Reade has not made use of really isolated spiral vessels in his analysis, since he expressly asserts it; but he does not once mention the remotest attempt to separate the interior matter from the cells and vessels, which necessarily must have been done if any value were to be attached to the result of the elementary analysis.

"This question arises with every one who knows that the greater part of vegetable tissue consists of a pellucid membrane, and the formations deposited on its inner surface: Are this membrane and the subsequent deposits formed of the same chemical substance? In fact, as we know from Mohl and Meyen that the increased thickness of the walls of cells consists of several layers, that even the spiral fibres are composed of an original fibre, and a subsequently deposited covering surrounding it, which I have found confirmed in innumerable instances, the further question arises whether both the single layers of incrustation, and the (additional?) parts of the spiral fibres, are not different from each other. As there can be no mechanical separation of such closely combined and microscopic parts, nothing can be done further than to superadd to chemical examination the use of the microscope, and by this means to observe the action of chemical reagents on the different elementary parts of the vegetable structure.

"I. I had made fine sections of an internodium of Arundo Donax an inch in diameter, and boiled them for some minutes in a solution of caustic potash. On bringing the section again under the microscope I was surprised by a peculiar appearance. A few ringed and spiral vessels were cut through, so that one could plainly see the section of their very thick fibre. By the boiling in caustic potash the spiral vessel was acted upon in its different parts in a very peculiar manner. The exterior enveloping membrane (the original wall of the cell) was apparently not in the slightest degree altered; it was still firm, close, transparent, and clear as water. The fibre itself consisted of two component parts; namely, of a (primary?) fibre lying close to the wall of the cell, and of an enveloping membrane surrounding the fibre on the three free sides in the interior of the cell. The caustic potash had coloured this enveloping membrane of a somewhat darker yellow, otherwise it was firm and apparently unaltered; the primary fibre, on the contrary, was changed into a gelatinous mass, so that on the plane of the section it was swelled up into a pretty considerable elevation. Unfortunately I did not follow up or vary these interesting observations, till after I had thrown away the remainder of the fresh piece of the Donax.

"II. The next experiment I instituted was on the leaves of Pleurothallis ruscifolia. The greater part of the cells of this plant contain beautiful spiral fibres, which appear to grow firmly against the walls of the cells. These fibres are all very broad and flat, like a riband, their thickness varying according to their position. Those cells which are situated vertically, immediately under the epidermis of the under side of the leaf, contain a thicker fibre than the less regularly formed cells, which are separated from the latter by a layer of green parenchyma, and from the upper epidermis of the leaf by an occasionally broken layer of colourless cells, mostly with plain walls. After I had boiled fine sections of this leaf in caustic potash for a few minutes, and again examined them, I found that the spires of the first-mentioned layer had become entirely separated from the walls of the cells. Under the simple microscope I could easily tear up single cells with a needle, and isolate the whole spiral fibre uninjured. Moreover, all the fibres were tumefied, and had acquired a gelatinous appearance from the action of the caustic potash. I now added a drop of sulphuric acid, which neutralised the potash with effervescence, and I then added an alcoholic solution of iodine. On again bringing the object under the microscope I was most agreeably surprised. All the spiral fibres, according to the varying thickness of the section (hence the unequal action of the caustic potash), appeared of different shades, from claret colour to the deepest violet. In those places where the section was not more than a single cell in thickness, a difference between the fibres in the above-mentioned layers was visible, inasmuch as those of the under side of the leaf (the thickest), even where they were most deeply coloured, did not appear of a pure violet colour, but redder, somewhat as if there had been a slight addition of orange. These fibres were also evidently less tumid, and the boundaries were more clearly defined. Those in the middle of the leaf, on the contrary, appeared quite gelatinous, and were coloured of a light blue. The membrane of the cells was in all cases clear as water, and colourless. This was not all: those cells which contained no spiral fibres, and which before, when magnified 230 times, appeared to consist of quite simple walls, even those of the green parenchyma, appeared now completely pitted; the primitive membrane and its pits were clear as water, and colourless, whilst the pits of the thickening layer were of a violet colour.

" III. I now took for comparison a woody stalk of Rosmarinus officinalis, and treated it in precisely the same manner. The result differed slightly from the above. The cells of the pith are here very thick-sided and pitted, as are also the exterior cells. The wood consists of the medullary sheath, of spiral vessels, and of prosenchymatous cells, the walls of which are just like the woody cells of very young coniferous wood. Here, in every part except the youngest annual rings, the original membrane (even of the spiral vessels) was not coloured, whilst those parts superposed, and even the spiral fibres, were deep orange. The cells of the youngest annual ring, on the contrary, appeared slightly pitted and very pale blue.

" IV. A species of Pelargonium, when submitted to the same action, gave the same results, only that the thin-walled but pitted exterior cells were also coloured blue.

" V. In the Teltow Turnip and Carrot, the primitive walls of the cells remained colourless; the incrusting layers of the same became blue; whilst, on the contrary, the fibres of the spiral and reticulated vessels became deep orange.

" VI. The spiral fibres, in the cells of a leaf of Oncidium altissimum, which had been preserved for seven months in weak alcohol (of about 30°), were coloured orange. The spires here consist, however, of two parts, which on the plane of the section could be easily distinguished, as in Arundo Donax; and I imagine that the spire in Pleurothallis consists only of the inner original fibre. I was not able to institute any experiments with fresh leaves of this plant, and have therefore not been able to decide this question with certainty. The original cellular membrane remained here, as in the first-mentioned cases, colourless, and the layers of increase became blue.

" VII. Opuntia monacantha gave the same results. In all the cells which were completely converted into wood, the additional layers, whether spiral or pitted, became of a deep orange colour, those of the pith and bark blue, and the primary cellular membrane still remained clear as water.

" An Echinocactus gave the same result.

" VIII. The wood of Betula alba and Populus tremula, when submitted to the above manipulation, showed nothing but pitted formations, the primitive membrane of which remained colourless, whilst the layers of increase were coloured dark orange.

" IX. A five years' old shoot of the trunk of Pinus silvestris gave, as regards the original walls of the cells, confirmation of the former constant results. The layers of increase were coloured orange, the cells of the bark and the youngest annual rings light blue.

" It is of course to be understood, that, by comparative experiments on all these plants, I had previously satisfied myself of the absence of starch in the cells in question.

" The foregoing, though only preliminary experiments, seem to indicate the following results: —

" 1. Vegetable tissue consists of three distinct chemical substances: —

a. The original membrane of the cells.
b. The primary layers upon this.
c. The secondary layers.

" 2. The first substance (1. *a.*) undergoes no apparent change by a short boiling in caustic potash.

"3. The second (1. *b.*) by short boiling in the caustic alkali is converted into starch, carbonic acid being evolved (granting that starch is the only substance upon which iodine acts so characteristically).

"4. The third (1. *c.*) by boiling in caustic potash is converted into a peculiar, as yet unknown (?), vegetable principle, which is coloured orange yellow by iodine. Whether in this case carbonic acid be also formed, I will not take upon myself to decide; at least in Experiment VIII., on the addition of sulphuric acid, I did not observe any effervescence. Moreover, this orange colour is as distant as heaven from earth, from the colour produced by adding iodine to vegetable mucus.

"Whether the carbonic acid be formed at the expense of the carbon of the vegetable substance uniting with the oxygen of the air, or by the decomposition of the water, remains still to be investigated; as, likewise, to discover whether by longer boiling, it could take up more carbon, and become converted into oxalic acid.

"The most interesting result is, however, without doubt, that, by the action of the caustic potash, one portion of vegetable matter becomes, by a retrograde metamorphosis, as it were, again converted into starch; a discovery, the extension of which gives promise of most interesting results for organic chemistry."

M. Payen selected with the utmost care the nascent tissue of the ovules of the Almond, Apple, and Sunflower; the half-formed tissue of the Cucumber; the sap of the same plant; the two months' old pith of the Elder; the pith of Æschynomene paludosa; the hairs of Cotton; and the new tissue of spongioles. They gave him the following results: —

	Almond.	Apple.	Sunflower.	Sap of Cucumber.	Tissue of Cucumber.	Elder.	Average of Æschynomene.	Average of Cotton.	Spongioles.
Carbon -	43·57	44·7	44·1	43·9	43·8	43·37	43·31	44·67	43·
Hydrogen -	6·11	6·	6·2	6·22	6·11	6·04	6·9	5·68	6·18
Oxygen -	50·32	49·3	49·7	49·88	50·1	50·59	50·1	49·3	50·82

But when he came to analyse wood in which a deposit had taken place, he found these proportions materially altered; the numbers being

	Oak.	Beech.	Herminiera.
Carbon - -	54·44	54·35	47·18
Hydrogen - -	6·24	6·25	5·94
Oxygen - -	39·32	39·5	46·88

When, however, the tissue was acted upon by such agents as have the property of destroying the matter of lignification, the proportions of the three fundamental principles approached more nearly those of primitive tissue.

	Oak treated with Soda.	Beech treated with Soda.	Aspen.		Oak and Beech treated in concentrated Nitric Acid, and afterwards washed with Soda.
			Washed once with Soda.	Washed twice with Soda.	
Carbon -	49·68	49·4	48·	47·71	43·85
Hydrogen -	6·02	6·13	6·4	6·42	5·86
Oxygen -	44·30	44·47	45·56	45·87	50·28

With reference to the discrepancy between the first and last of these tables, Payen remarks that, as alkalies do not remove all the matter of lignification, it is possible that this substance may consist of two kinds of matter, one of which only is capable of being acted upon by azotic acid. He also adds that, although concentrated sulphuric acid has the same power as nitric acid of separating from the primitive tissue of plants their sedimentary matter, yet it possesses this difference, that it gives it the property of becoming blue when acted upon by iodine; a circumstance which has doubtless given rise to the statement that lignine may be transformed into starch. (*Comptes rendus*, vii. 1055. 1125.)

CHAPTER II.

ELEMENTARY ORGANS.

THE general properties of the elementary organs are, *elasticity*, *extensibility*, *contractibility*, and *permeability* to fluids or gaseous matter. The first gives plants the power of bending to the breeze, and of swaying backwards and forwards without breaking. The second enables them to develope with great rapidity when it is necessary for them to do so, and also to give way to pressure without tearing. The third causes parts that have been overstrained to recover their natural dimensions when the straining power is removed, and it permits the mouths of wounded vessels to close up so as to prevent the loss of their contents. The fourth secures the free communication of the fluids through every part of a plant which is not choked up with earthy matter.

The special properties of the elementary organs must be considered separately.

That of these the CELLULAR TISSUE is the most important is apparent by its being the only one of the elementary organs which is uniformly present in plants; and by its being the chief constituent of all those compound organs which are most essential to the preservation of species.

It transmits fluids in all directions. In most cellular plants no other tissue exists, and yet in them a circulation of sap takes place; it constitutes the whole of the medullary rays, conveying the elaborated juices from the bark towards the centre of the stem; all the parenchyma in which the sap is diffused upon entering the leaf, and by which it is exposed to evaporation, light, and atmospheric action, consists of cellular tissue; much of the bark in which the descending current of the sap takes place is also composed of it; and in endogenous plants, where no bark exists, there appears to be no other route that the descending sap can take, than through the cellular substance in which the vascular system is embedded. It is, therefore, readily permeable to fluid, although it has no visible pores.

In all cases of wounds, or even of the developement of new parts, cellular tissue *is first generated:* for example, the granulations that form at the extremity of a cutting when embedded in earth, or on the lips of incisions in the wood or bark; the extremities of young roots; scales, which are generally the commencement of leaves; pith, which is the first part created, when the stem shoots up; nascent stamens and pistils; ovules; and, finally, many rudimentary parts: in all these at first, or constantly, is formed cellular tissue alone.

It is that from which leaf-buds are generated. These organs always appear from some part of the medullary system; when adventitious, from the ends of the medullary rays if developed by stems, or from the parenchyma if appearing upon leaves.

It may be considered *the flesh of vegetable bodies.* The matter which surrounds and keeps in their place all the ramifications or divisions of the vascular system is cellular tissue. In it the plates of wood of exogenous plants, the woody bundles of endogenous plants, the veins of leaves, and, indeed, the whole of the central system of all of them, are either embedded or enclosed.

The action of fertilisation appears to take place exclusively through its agency. Pollen is only cellular tissue in a particular state; the coats of the anther are composed entirely of it; and the tissue of the stigma, through which fertilisation is conveyed to the ovules, is merely a modification of the cellular. The ovules themselves, with their sacs, at the time they receive the vivifying influence, are a semitransparent congeries of cellules.

It is, finally, *the tissue in which chiefly amylaceous or saccharine secretions are deposited.* These occur chiefly in tubers, as in the Potato and Arrow-root; in rhizomata, as in the Ginger; in soft stems, such as those of the Sago-Palm and Sugar-cane; in albumen, as that of Corn; in pith, as in the Cassava; in the disk of the flower, as in Amygdalus; and, finally, in the bark, as in all exogenous plants; and cellular tissue is the principal, or exclusive, constituent of these.

In the form of articulated BOTHRENCHYMA, when it is collected together into hollow cylinders, it serves for the rapid transmission of fluids in the direction of the stem; and it is well worth notice, that the size of the tubes of articulated bothrenchyma, and their abundance, are usually in proportion to the length to which the fluid has to be conveyed. Thus in the Vine, Phytocrene, the common Cane, and such plants, the pitted tissue is unusually large and abundant; in ordinary trees much less so; and in herbaceous plants it hardly exists. Bothrenchyma eventually ceases to convey fluid, and becomes filled with air. The use of other kinds of bothrenchyma is not known.

PLEURENCHYMA is apparently destined for the conveyance of fluid upwards or downwards, from one end of a body to another, and for giving firmness and elasticity to every part.

That it is intended *for the conveyance of fluid* in particular channels seems to be proved: 1. from its constituting the principal part of all wood, particularly of that which is formed in stems the last in each year, and in which fluid first ascends in the ensuing season; 2. from its presence in the veins of leaves where a rapid circulation is known to take place, forming in those plants both the adducent and reducent channels of the sap; and, 3., from its passing downwards from the leaves into the bark, thus forming a passage through which the peculiar secretions may, when elaborated, arrive at the stations where they are finally to be deposited. Knight is clearly of opinion that it conveys fluid either upwards or downwards; in which I fully concur with him: the power of cuttings to grow when inverted seems, indeed, a conclusive proof of this. Dutrochet, however, endeavours to prove that it merely serves for a downward conveyance.

With regard *to its giving firmness and elasticity to every part*, we need only consider its surprising tenacity, as evinced in hemp, flax, and the like; and its constantly surrounding and protecting the ramifications of the vascular system, which has no firmness or tenacity itself. To this evidence might be added, the admirable manner in which it is contrived to answer such an end. It consists, as has been seen, of lignified slender tubes, each of which is indeed possessed of but a slight degree of strength; but being of different lengths, tapering to each extremity, and overlapping each other in various degrees, these are consolidated into a mass which considerable force is insufficient to break. Any one who will examine a single thread of the finest flax, with a microscope which magnifies only 180 times, will find that what to the eye appears a single thread is in reality composed of a great number of distinct tubes.

It is also the tissue from which roots are emitted. Unlike the leaf-buds, roots are always prolongations of the woody tissue of the stem, as may be seen by tracing a young root to its origin. The woody tissue, when applied to this purpose, is, however, always covered with cellular tissue.

The real nature of the functions of the VASCULAR SYSTEM has been the subject of great difference of opinion. *Spiral vessels* have been most commonly supposed to be destined for the conveyance of air; and it seems difficult to conceive how any one accustomed to anatomical observations, and who has remarked their dark appearance when lying in water, can doubt that fact. Nevertheless, many observers, and among them Dutrochet, assert that they serve for the transmission of fluids upwards from the roots. This physiologist states that, if the end of a branch be immersed in coloured fluid, the latter will ascend in both the spiral vessels and articulated bothrenchyma; but that in the former it will only rise up to the level of the fluid in which the branch is immersed, while through the latter it will travel into the extremities of the branches. But from this statement it does not appear that spiral vessels convey fluid; it only shows that M. Dutrochet confounds one kind of tissue with another, when he infers that trachenchyma performs certain functions, because such functions are proper to bothrenchyma in a particular state. It has also been asked, how the opinion that spiral vessels are the sap-vessels is to be reconciled with the fact of their non-existence in multitudes of plants in which the sap circulates freely. To which might have been, or perhaps has been, added the question, why they do not exist in the wood, where a movement of sap chiefly takes place in exogenous trees. And further, it has always been remarked, that, if a tranverse section of a Vine, for instance, or any other plant, be put under water, bubbles of air rise through the water from the mouths of the spiral vessels. But then, it has been urged, that coloured fluids manifestly rise in the spiral vessels; a statement which has been admitted when the spiral vessels are wounded at the part plunged in the colouring fluid, but denied in other circumstances. Indeed, to persons acquainted with the difficulty of microscopic investigations, the obscurity that practically surrounds a question of this sort must be apparent enough.

Kützing, adopting the views of Schulthess and Oken, has recently asserted that the spiral vessels represent the nervous system of plants; and that both they and the tubes of pleurenchyma perform the same office in the system of vegetable vitality, as metallic wires in conducting electromagnetical currents. (*Linnæa*, xii. 26. Schulthess, *Drei Vorlesungen über Electromagnetismus, gehalten in der naturforschenden Gesellschaft zu Zurich:* 1835.)

The use of spiral vessels has been investigated with care by Bischoff, who instituted some delicate and ingenious experiments, for the purpose of determining the real contents and office of the spiral vessels. It is impossible to find room here for a detailed account of his experiments, for which the reader is referred to his thesis, *De vera Vasorum Plantarum Spiralium Structura et Functione Commentatio:* Bonnæ, 1829. It must be sufficient to state, that, by accurate chemical tests, by a careful purification of the water employed from all presence of air, and by separating bundles of the spiral vessels of the Gourd (Cucurbita Pepo), and of some other plants from the accompanying cellular substance, he came to the following conclusions, which, if not exactly, are probably substantially, correct:—"That plants, like all other living bodies, require, for the support of their vital functions, a free communication with air; and that it is more especially oxygen which, when absorbed by the roots from the soil, renders the crude fluid fit for the nourishment and support of a plant, just as blood is rendered fit for that of animals. But, for this purpose, it is not sufficient that the external surface should be surrounded by the atmosphere; other aëriferous organs are provided, in the form of spiral vessels, which are placed internally, and convey air containing an unusual proportion of oxygen, which is obtained through the root, by their own vital force, from the earth and water. In a hundred parts of this air twenty-seven to thirty parts are of oxygen, which is in part lost during the day by the surface of plants under the direct influence of the solar rays."

With such evidence of the aëriferous functions of the spiral vessels, it will doubtless to many appear probable that this question is settled, as far as spiral vessels, properly so called, are concerned. Whether or not *ducts* have a different function is uncertain; it is probable, however, from the extreme thinness of their sides, that they are really filled with fluid when full grown, whatever may have been the case when they were first generated.

Link, who formerly considered trachenchyma a part of the aëriferous system, now declares its function to be that of conveying nutritious secretions. (*Element.* ed. 2. i. 188.) He considers his new opinion proved by certain plants, which he had grown in a solution of prussiate of potash, having had their spiral vessels stained blue when afterwards grown in sulphate of iron. (See APPENDIX.)

Gaudichaud has also been appealed to, as being of the same opinion; but this botanist seems to have ascertained nothing more than that articulated bothrenchyma conveys fluid, which is a very different thing. (See *Ann. des Sc.*)

It requires no argument to prove that the office of CINENCHYMA is to convey the elaborated sap of a plant to the places where it is needed, and especially down the inner parts of the bark of oxygens. For all details concerning this matter, we must wait for the appearance of Professor Schultz's memoir.

In regard to the functions of *air-cells* and *lacunæ*, it may be sufficient to remark, that in all cases in which they form a part of the vital system, as in water plants, they are cavities regularly built up of cellular tissue, and uniform in figure in the same species; while, on the other hand, where they are not essential to vitality, as in the pith of the Walnut, the Rice-paper plant, the stems of Umbelliferæ, and the like, they are ragged, irregular distentions of the tissue. In the former case they are intended to enable plants to float in water; in the latter, they are caused by the growth of one part more rapidly than another.

CHAPTER III.

OF SYMMETRY.

When the elementary organs combine themselves into an organised structure endowed with life, they produce a body, 1. invariably bounded by curved lines, and, 2., having its parts balanced with great symmetry. In these respects they agree with the animal, and differ from the mineral, kingdom.

There is no such thing as an angle in vegetation: the points of the most acuminated leaves, the so-called angles of leaves and stems, the teeth of serrated leaves, are all in reality so many curves. Even the apparently flat surfaces of leaves and petals are only segments of large circles. This is a necessary consequence of the primitive spheroidal form of vegetable tissue, which, in whatever way it may develope, must always be bounded externally by the curved sides of the parenchyma.

In like manner, it will always be found, that every part of a plant is balanced by some other part. The stem is equipoised by the root; one leaf or pair of leaves is counterbalanced by the next leaf or pair; one side of a leaf answers to another; of the anthers, one lobe has its fellow on the opposite side of the connective; and this kind of comparison may be carried into the minutest part of vegetable structure. It is true, that it appears in some cases of irregularity to be departed from; as in Labiatæ and other irregular flowers, where the balance among the several parts seems to be destroyed; in such plants as Goldfussia anisophylla, in which one of every pair of opposite leaves is much smaller than the other; and in such leaves as those called by botanists oblique, in which one side of the leaf is much smaller than the other: but, even here, the symmetry is only destroyed in appearance. If in Labiatæ the force of developement preponderates in the anterior segments of the corolla, it is counterbalanced by the fuller developement of the posterior stamens and sepals; and in Leguminosæ, in which the posterior petal overbalances those in front, the anterior sepals and stamens restore the equipoise. If in Goldfussia it is the right hand-leaf of one pair which is the smaller, it is the left leaf of the next pair.

In the arrangement of the organs round the axis of a plant, the same careful provision of antagonistic developement is manifest. If one leaf grows on the right of a stem, the next appears on the left, the next on the right; if a pair of opposite leaves points N. and S., the next pair points E. and W., the next N. and S. again; and, if a whorl of 4 leaves is directed to the cardinal points, the next whorl is directed to the intermediate points of the compass, and so on. The same laws will be found to be observed, with little variation, through all the organs of a flower.

Messrs. Chatin and Moquin Tandon have been led, by such considerations as these, to assume that there are in the vegetable, as in the animal, kingdom, both a centripetal and centrifugal force of developement; the former appertaining to Exogens and Endogens, and the latter to Acrogens. I know nothing of the evidence upon which M. Chatin thinks this proposition may be maintained. M. Moquin Tandon has, however, given a sketch of his ideas upon the same subject, and I must confess they do not appear to me conclusive. (See *Comptes rendus*, v. 691.)

CHAPTER IV.

OF THE ROOT.

It is the business of the root to absorb nutriment from the soil, and to transmit it upwards into the stem and leaves; and also to fix the plant firmly in the earth. Although moisture is, no doubt, absorbed by the leaves and bark of all, and by the stems of many, plants, yet it is certain that the greater part of the food of plants is taken up by the roots; which, hence, are not incorrectly considered vegetable mouths.

But it is not by the whole surface of the root that the absorption of nutriment takes place; it is the spongioles almost exclusively to which that office is confided: and hence their immense importance in vegetable economy, the absolute necessity of preserving them in transplantation, and the certain death that often follows their destruction. This has been proved in the following manner, by Senebier:—He took a radish, and placed it in such a position that the extremity only of the root was plunged in water: it remained fresh several days. He then bent back the root, so that its extremity was curved up to the leaves: he plunged the bent part in water, and the plant withered soon; but it recovered its former freshness upon relaxing the curvature, and again plunging the extremity of the root into the water.

This explains why forest trees, with very dense umbrageous heads, do not perish of drought in hot summers or dry situations, when the earth often becomes mere dust for a considerable distance from their trunk, in consequence of their foliage turning off the rain: the fact is obviously that the roots near the stem are inactive, and have little or nothing to do as preservatives of life except by acting as conduits, while the functions of absorption go on through the spongioles, which, being at the extremities of the roots, are placed beyond the influence of the branches, and extend wherever moisture is to be found.

This property prevents a plant from exhausting the earth in which it grows; for, as the roots are always spreading further and further from the main stem, they are continually entering new soil, the nutritious properties of which are unexhausted.

It is generally believed that roots increase *only* by their extremities, and that, once formed, they never undergo any subsequent elongation. This was first noticed by Du Hamel, who passed fine silver threads through young roots at different distances, marking on a glass vessel corresponding points with some varnish: all the threads, except those that were within two or three lines of the extremity, always continued to answer to the dots of varnish on the glass vessel, although the root itself increased considerably in length. Variations in this experiment, which has also been repeated in another way by Knight, produced the same result, and the whole phenomenon appears to be one of those beautiful evidences of design which are so common in the vegetable kingdom. If plants growing in a medium of unequal resistance lengthened by an extension of their whole surface, the nature of the medium in which they grow would be in most cases such as the mere force of their elongation would be unable to overcome; and the consequence would be, that they would have a twisted, knotted, unequal form, which would be eminently unfavourable to the rapid transmission of fluid, which is their peculiar office. Lengthening, however, only at the extremities, and this by the continual formation of new matter at their advancing point, they insinuate themselves with the greatest facility between the crevices of the soil; once insinuated, the force of horizontal expansion speedily enlarges the cavity; and if they encounter any obstacle which is absolutely insurmountable, they simply stop, cease growing in that particular direction, and follow the surface of the opposing matter, till they again find themselves in a soft medium.

It is curious, however, to remark that, although this property of lengthening only by the ends of their roots seems constant in most plants, yet that it is not impossible that it may be confined to roots growing in a resisting medium. From the following experiments it will be seen that in Orchidaceæ the root elongates independently of its extremity: — On the 5th of August I tied threads tightly round the root of a Vanilla, so that it was divided into three spaces, of which one was 7 inches long; another 4 inches; and the third, which was the free-growing extremity, 1⅜ inch. On the 19th of September the first space measured 7⅛ inches; the second, 4⅜ inches; and the third, or growing extremity, 2⅛ inches. A root of Aerides cornutum was, on the 5th of August, divided by ligatures into spaces, of which the first measured 1 foot 3 inches; the second, 2¼ inches; the third, 3⅛ inches; and the fourth, or growing end, 1⅛ inch. On the 19th of September, the first space measured 1 foot 3½ inches; the second, 2¾ inches; the third, 3¼ inches; and the fourth, 4¾ inches.

Occasionally roots appear destined to act as reservoirs of nutriment on which those of the succeeding year may feed when first developed, as is the case in the Orchis, the Dahlia, and others. But it must be remarked, that the popular notion extends this circumstance far beyond its real limits, by including among roots bulbs, tubers, and other forms of stem in a succulent state.

By some botanists, and among them by De Candolle, it has been thought that roots are developed from special organs, which are to them what leaf-buds are to branches; and this function has been assigned to those little glandular swellings so common on the Willow, called *lenticular glands* by Guettard, and *lenticelles* by De Candolle.

According to Knight, the energies of a variety artificially produced exists longer in the system of the root than in that of the stem; so that it is more advisable to propagate old varieties of fruit trees from cuttings of the root than from those of the stem.

The roots not only absorb fluid from the soil, but they return a portion of their peculiar secretions back again into it; as has been found by Brugmans, who ascertained that the Pansy exuded an acid fluid from its spongioles; and by others, who found that various Euphorbiaceous and Cichoraceous plants form little knobs at the extremity of their roots. Recently more important enquiries into this subject have been made by Macaire, who, in a paper in the *Transactions of the Physical Society of Geneva*, has given an account of his important experiments, of which the following is an abstract: — He found that Chondrilla muralis, and Cichoraceous plants in general, secreted a matter analogous to opium; Leguminous plants, a substance similar to gum, with a little carbonate of lime; Grasses, a minute quantity of matter consisting of alkaline and earthy muriates and carbonates, with very little gum; Papaveraceous plants, a matter analogous to opium; and Euphorbias, a whitish yellow gum, and resinous matter of an acrid taste.

He also found that plants actually possess the power of freeing themselves from matter that is deleterious to them, by means of their roots. Acetate of lead is a well-known active vegetable poison; he took two bottles, one of which, A, was filled with pure water, and the other, B, with water holding acetate of lead in solution. He placed a plant of Mercurialis annua with half its roots plunged in A, and the other half in B. After a short time the water in the bottle A contained a notable proportion of acetate of lead, which must have been carried into the system by the roots in bottle B, and thrown off again by those in bottle A. He also states that various plants which had lain several days in water charged with lime, or acetate of lead, or nitrate of silver, or common salt, in small quantity, having been carefully washed and placed in pure water, gave back from their roots the deleterious matter they had absorbed.

It is difficult to speculate upon the results to which this curious discovery may lead. It is perhaps an explanation of the necessity of the rotation of crops, of the action of what are called weeds, of the utility of changing the earth of plants growing in pots, and of other phenomena which could not previously be accounted for. It requires, however, a great deal of ulterior examination; but as the enquiry has been taken up by Dr. Daubeny, the learned Professor of Botany and Chemistry at Oxford, at the instance of the British Association, it is not to be doubted that a few years will throw much additional light upon the subject.

M. Payen has ascertained (*Ann. des Sc.*, n. s., iii. 18.) that the roots of plants contain a large proportion of azotised matter, which is so abundant in the spongioles, as immediately to give off ammoniacal vapours when decomposed by aid of heat. Aerial roots, especially those of many species of Pothos, contain more than such as are subterranean. This azotised matter is almost or entirely insoluble in water, and adheres inseparably to the cellular tissue: it is most abundant at the points of the spongioles, and gradually disappears in the interior of the root. It appears essential to the life of plants, and its large proportion at the extremities of the roots may help to explain why azotised manures are so peculiarly efficient. It also shows how the well known destructive effects of tannin upon roots take place, by precipitating the azotised matter, which is essential to the existence of roots.

CHAPTER V.

OF THE STEM AND THE ORIGIN OF WOOD.

THE general purpose of the stem is, to bear the leaves and other appendages of the axis aloft in the air, so that they may be freely exposed to light and atmospheric action; to convey fluids from the root upwards, and from above downwards; and, if woody, to store up a certain portion of the secretions of the species either in the bark or in the heartwood.

Various notions have from time to time been entertained about the PITH. The functions of brain, lungs, stomach, nerves, spinal marrow, have by turns been ascribed to it. Some have thought it the seat of fecundity, and have believed that fruit trees deprived of pith became sterile; others supposed that it was the origin of all growth; and another class of writers have declared that it was the channel of the ascent of sap. It is, however, no part of the plan of this work to refute these and similar exploded speculations.

It is probable that its real and only use is, to serve, in the infancy of a plant, for the reception of the sap upon which the young and tender vessels that surround it are to feed when they are first formed; a time when they have no other means of support. Dutrochet considers it to act not only as a reservoir of nutriment for the young leaves, but also to be the place in which the globules which he calls nervous corpuscles are formed out of the elaborated sap (*L'Agent Immédiat*, &c. p. 44. &c.); and Braschet imagines it and its processes to constitute the nervous system of plants!

The MEDULLARY SHEATH seems to perform an important part in the economy of plants; it diverges from the pith whenever a leaf is produced; and, passing through the petiole, ramifies among the cellular tissue of the blade, where it appears as veins: hence veins are always composed of bundles of woody tissue and spiral vessels. Thus situated, the veins are in the most favourable position that can be imagined for absorbing the fluid which, in the first instance, is conducted to the young pith, and which is subsequently impelled upwards through the woody tissue. So essential is the medullary sheath to vegetation in the early age of a branch, that, as is well known, although the pith and the bark, and even the young wood, may be destroyed, without the life of a young shoot being much affected; yet, if the medullary sheath be cut through, the pith, bark, or wood, being left, the part above the wound will perish. It may be supposed, considering the large proportion of oxygen it contains, that its office is in part to convey that gas to parts inaccessible to the external air, where it may combine with the carbon of such parts, and cause the production of carbonic acid; without a power of composing and decomposing which, no part exposed to light can long exist.

The BARK acts as a protection to the young and tender wood, guarding it from cold and external accidents. It is also the medium in which the proper juices of the plant, in their descent from the leaves, are finally elaborated, and brought to the state which is peculiar to the species. It is from the bark that they are horizontally communicated to the medullary rays, which deposit them in the tissue of the wood. Hence, the character of timber is almost wholly dependent upon the influence of the bark, as is apparent from a vertical section of a grafted tree, through the line of union of the stock and scion. This line will be sometimes found so exactly drawn, that the limits of the two are well defined even in old specimens: the woody tissue will be found uninterruptedly continuous through the one into the other, and the bark of the two indissolubly united; but the medullary rays emanating from the bark of each will be seen to remain as different as it was at the time when the stock and scion were distinct individuals. It is to be remarked, however, that bark has only a limited power of impelling secreted matter into the medullary rays; and that there are certain substances which, although abundant in bark, are scarcely found elsewhere; as, for instance, gum in a Cherry tree. This substance exists in the wood in so slight a degree as probably not to exceed in quantity what is to be found in most plants, whether they are obviously gummiferous or not. Are we from this to infer that the medullary rays have a power of rejecting certain substances? or, that their tissue is impermeable to fluids of a particular degree of density? or, that they only take up what settles down the bark through its cellular system, and that gum, descending by the woody system exclusively, is not in that kind of contact with the medullary rays which is required to enable the latter to take it up? or, that the latex, which flows exclusively through the cinenchyma, mingles but little with the medullary parenchyma?

As the bark, when young, is green like the leaves, and as the latter are manifestly a mere dilatation of the former, it is highly probable, as Knight believes, that the bark exercises an influence upon the fluids deposited in it wholly analogous to that exercised by the leaves, which will be hereafter explained. Hence it has been named, with much truth, the universal leaf of a vegetable. In fact, in succulent Cactaceæ, Stapelias, and similar plants, there is no other part capable of performing the function of leaves.

The business of the MEDULLARY RAYS is, no doubt, exclusively to maintain a communication between the bark, in which the secretions receive their final elaboration, and the centre of the trunk, in which they are at last deposited. This is apparent from tangental sections of dicotyledonous wood manifesting an evident exudation of liquid matter from the wounded medullary rays, although no such exudation is elsewhere visible. In endogenous plants, in which there appears less necessity for maintaining a communication between the centre and circumference, there are no special medullary rays. These rays also serve to bind firmly together the whole of the internal and external parts of a stem, and they give the peculiar character by which the wood of neighbouring species may be distinguished. If plants had no medullary rays, their wood would probably be, in nearly allied species, undistinguishable; for we are scarcely aware of any appreciable difference in the appearance of woody or vascular tissue; but the medullary rays (the *silver grain* of carpenters), differing in abundance, in size, and in other respects, impress characters upon the wood which are extremely well marked. Thus, in the cultivated Cherry, the plates of the medullary rays are thin, the adhesions of them to the bark are slight, and hence a section of the wood of that plant has a pale, smooth, homogeneous appearance; but in the wild Cherry the medullary plates are much thicker, they adhere to the bark by deep broad spaces, and are arranged with great irregularity, so that a section of the wood of that variety has a deeper colour, and a twisted, knotty, very uneven appearance. In Quercus sessiliflora the medullary rays are thin, and so distant from each other that the plates of wood between them do not readily break laterally into each other, if a wedge is driven into the end of the trunk in the direction of its cleavage: on the contrary, the medullary rays of Quercus pedunculata are hard, and so close together that the wood may be rent longitudinally without difficulty; hence the wood of the latter is the only kind that is fit for application to park paling.

As the medullary rays develope in a horizontal direction only, when two trees in which they are different are grafted or budded together, the wood of the stock will continue to preserve its own peculiarity of *grain*, notwithstanding its being formed by the woody matter sent down by the scion; for it is the horizontal developement that gives its character to the "grain of wood," and not the perpendicular pleurenchyma encased in it.

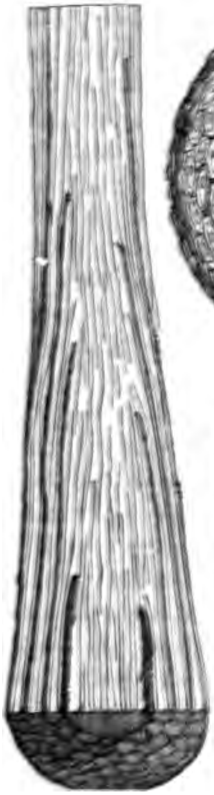
The WOOD is at once the support of all the deciduous organs of respiration, digestion, and fertilisation; the depositary of the secretions peculiar to individual species; and also the reservoir from which newly forming parts derive their sustenance, until they can establish a communication with the soil.

Regarding the precise manner in which it is created, there has been great diversity of opinion. Linnæus thought it was produced by the pith; Grew, that the liber and wood were deposited at the same time in a single mass which afterwards divided in two, the one half adhering to the centre, the other to the circumference. Malpighi conceived that the wood of one year was produced by an alteration of the liber of the previous season. Duhamel believed that it was deposited by the secretion already spoken of as existing between the bark and wood, and called cambium: he was of opinion that this cambium was formed in the bark, and became converted into both cellular and woody tissue; and he demonstrated the fallacy of those theories according to which new wood is produced by the wood of a preceding year. He removed a portion of bark from a Plum tree; he replaced this with a similar portion of a Peach tree, having a bud upon it. In a short time a union took place between the two. After waiting a sufficient time to allow for the formation of new wood, he examined the point of junction, and found that a thin layer of wood had been formed by the Peach bud, but none by the wood of the Plum, to which it had been tightly applied. Hence he concluded that alburnum derives its origin from the bark, and not from the wood. Many similar experiments were instituted with the same object in view, and they were followed by similar results. Among others, a plate of silver was inserted between the bark and the wood of a tree, at the beginning of the growing season. It was said, that, if new wood were formed by old wood, it would be subsequently found pushed outwards, and continuing to occupy the same situation; but that, if new wood were deposited by the bark, the silver plate would in time be found buried beneath new layers of wood. In course of time the plate was examined, and was found enclosed in wood.

Hence the question as to the origin of the wood seemed settled; and there is no doubt that the experiments of Duhamel are perfectly accurate, and satisfactory as far as they go. It soon, however, appeared, that, although they certainly proved that new wood is not produced by old wood, it was not equally clear that it originated from the bark. Accordingly a new set of experiments was instituted by Knight, for the purpose of throwing a still clearer light upon the production of the wood. Having removed a ring of bark from above and below a portion of the bark furnished with a leaf, he remarked that no increase took place in the wood above the leaf, while a sensible augmentation was observable in the wood below the leaf. It was also found, that, if the upper part of a branch be deprived of leaves, the branch will die down to the point where leaves have been left, and below that will flourish. Hence an inference is drawn, that the wood is not formed out of the bark as a mere deposit from it; but that it is produced from matter elaborated in the leaves and sent downwards, either through the vessels of the inner bark, along with the matter for forming the liber, by which it is subsequently parted with; or that it and the liber are transmitted distinct from one another, the one adhering to the alburnum, the other to the bark. I know of no proof of the former supposition; of the latter there is every reason to believe the truth. Knight is of opinion that two distinct sets of vessels are sent down, one belonging to the liber, the other to the alburnum; and if a branch of any young tree, the wood of which is formed quickly, be examined when it is first bursting into leaf, these two sets may be distinctly seen and traced. Take, for instance, a branch of Lilac in the beginning of April, and strip off its bark: the new wood will be distinctly seen to have passed downwards from the base of each leaf, diverging from its perpendicular course, so as to avoid the bundle of vessels passing into the leaf beneath it; and, if the junction of a new branch with that of the previous year be examined, it will be found that the wood already seen proceeding from the base of the leaves, having arrived at this point, has not stopped there, but has passed rapidly downwards, adding to the branch an even layer of young ligneous matter, and turning off at every projection which impedes it, just as the water of a steady but rapid current would be diverted from its course by obstacles in its stream. Again, in Guaiacum wood, the descending tubes of pleurenchyma cross and interlace each other, in a manner that is unintelligible upon the supposition of wood being formed by the mere deposit of secreted matter. If the new wood were a mere deposit of the bark, the latter, as it is applied to every part of the old wood, would deposit the new wood equally over the whole surface of the latter, and the deviation of the fibres from obstacles in their downward course would scarcely occur. This, therefore, in my mind, places the question as to the origin of the wood beyond all further doubt. Or, if further evidence were required, it would be furnished by a case adduced by Achille Richard, who states that he saw, in the possession of Du Petit Thouars, a branch of Robinia Pseudacacia on which R. hispida had been grafted. The stock had died; but the scion had continued to grow, and had emitted from its base a sort of plaster formed of very distinct fibres, which surrounded the extremity of the stock to some distance, forming a kind of sheath; and thus demonstrating incontestably that wood does descend from the base of the scion to overlay the stock. The singular mode of growth in Pandanus is equally instructive. In that plant, the stem, next the ground, is extremely slender; a little higher up it is thicker, and emits aerial roots, which seek the soil and act as stays upon the centre. As the stem increases in height, it also increases notably in diameter, continuing to throw out aerial roots. If the roots were pruned away, the stem would be an inverted cone; but, if we add to the actual thickness of the base of the stem the capacity of the aerial roots at that part, the two together will be about equal to the capacity of the stem at the apex; which suggests the idea that the woody matter that descends from the leaves may really be their roots, passing through the horizontal cellular system of the stem. An analogous but much more remarkable case is the following mentioned by me in the *Penny Cyclopædia*, article Endogens, vol. ix. p. 396. In an unpublished species of Barbacenia from Rio Janeiro, allied to B. purpurea, the stems appear externally like those of any other rough-barked plant, only that their surface is unusually fibrous and ragged when old, and closely coated by the remains of sheathing leaves when young. Upon examining a transverse section of it, the stem is found to consist of a small, firm, pale, central circle having the ordinary endogenous organisation, and of a large number of smaller and very irregular oval spaces pressed closely together, but having no organic connection; between these are traces of a chaffy ragged kind of tissue which seems as if principally absorbed and destroyed. (See *fig*. 192.)

A vertical section of the thickest part of this stem exhibits, in addition to a pale, central, endogenous column, woody branches crossing each other or lying parallel, after the manner of the ordinary ligneous tissue of a Palm stem (*fig.* 193.), only the bundles do not adhere to each other, and are not embodied, as usual, in a cellular substance. These bundles may be readily traced to the central column, particularly in the younger branches (*fig.* 191.), and are plainly the roots of the stem, of exactly the same nature as those aerial roots which serve to stay the stem of a Screw Pine (Pandanus). When they reach the earth, the woody bundles become more apparently roots, divided at their points into fine segments, and entirely resembling on a small scale the roots of a Palm-tree. The central column is much smaller

191



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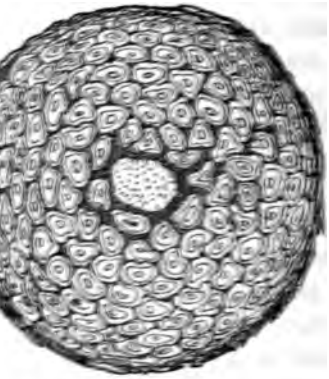

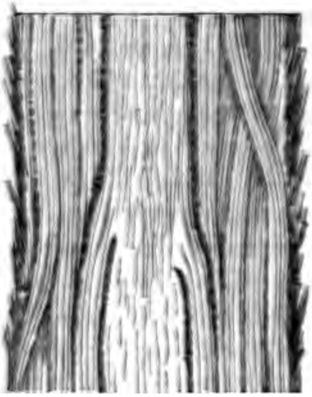

193

at the base of the stem, than near the upper extremity. Nothing can well show more distinctly than this, that the woody bundles of the endogenous stem are a sort of roots emitted by the leaves, plunging down through their whole length into the cellular substance of the stem in ordinary cases; but, in Barbacenia, soon quitting the stem, and continuing their course downwards on the outside. The observation of Du Petit Thouars, that, when Dracænas push forth branches, each of the latter produces from its base a quantity of fibres, which are interposed between the cortical integument and the body of the wood, forming a sort of plaster analogous to what is found in the graft of an Exogen; and that, of the fibres just mentioned, the lowermost have a tendency to descend, while those originating on the upper side of the branch turn downwards, and finally descend also; had already rendered the above-mentioned conclusion probable. The case of Barbacenia can scarcely leave a doubt upon the subject; and leads to the important conclusion, that the theory of the wood of Exogens being also a state of roots belonging to the leaves of the stem is well founded also.

Mirbel, who formerly advocated the doctrine of wood being deposited by bark, has candidly admitted the opinion to be no longer tenable; and he has suggested, in its room, that wood and bark are independent formations, which is no doubt true; but he adds, created out of cambium, in which it is impossible to concur, if by cambium M. Mirbel means the viscid secretion found in the spring between the bark and wood of Exogens; for the following reasons: — All the writers hitherto mentioned have considered the formation of wood exclusively with reference to exogenous trees, and to such only of them as are the common forest plants of Europe. Had they taken into account exotic trees or any endogenous plants, they would have seen that none of their theories could apply to the formation of wood in the latter tribe. In many Exogens of tropical countries, wood is not deposited in regular circles all round the axis, but only on one side of the stem, or along certain lines upon it: were it a deposit from the bark, or a metamorphosis of cambium, it would necessarily be deposited with some kind of uniformity.

In endogenous trees there is no cambium, and yet wood is formed in abundance; and in the centre, not in the circumference: so that bark can have, in such cases, nothing to do with the creation of wood.

But, if the word cambium is employed by M. Mirbel as an equivalent for organic mucus (see p. 1.), then the statement of this learned botanist is true, no doubt, but does not affect the question in dispute.

Aware of the difficulties in the way of the common explanations of the formation of wood, Du Petit Thouars, an ingenious French physiologist, who had possessed opportunities of examining the growth of vegetation in tropical countries, proposed a theory, which, although in many points similar to one previously invented by his countryman, De la Hire, is nevertheless, from the facts and illustrations brought by the French philosopher to his aid, to be considered legitimately as his own. The attention of Du Petit Thouars appears to have been first especially called to the real origin of wood by having remarked, in the Isle of France, that the branches emitted by truncheons of Dracæna (with which hedges are formed in that colony) root between the rind and old wood, forming rays, of which the axis of the new shoot is the centre. These rays surround the old stem; the lower ones at once elongate greatly towards the earth, and the upper ones gradually acquire the same direction; so that at last, as they become disentangled from each other, the whole of them pass downwards to the soil. Reflecting upon this curious fact, and upon others which I have not space to detail, he arrived at this conclusion; that it is not merely in the property of increasing the species that buds agree with seeds, but that they emit roots in like manner; and that the wood and liber are both formed by the downward descent of bud-roots, at first nourished by the moisture of the cambium, and finally embedded in the cellular tissue which is the result of the organisation of that secretion. That first tendency of the embryo, when it has disengaged itself from the seed, to send roots downwards and a stem and leaves upwards, and to form buds in the axils of the latter, is in like manner possessed by the buds themselves; so that plants increase in size by an endless repetition of the same phenomenon.

Hence a plant is formed of multitudes of buds or fixed embryos, each of which has an independent life and action: by its elongation upwards forming new branches and continuing itself, and by its elongation downwards forming wood and bark; which are therefore, in Du Petit Thouars's opinion, a mass of roots.

This opinion would probably have been more generally received, if it had not been too much mixed up with hypothetical statements, to the reception of which there are, in the minds of many persons, strong objections; as, for example, that mentioned in the last paragraph. The theory, nevertheless, seems better adapted than any other to explain the cause of the many anomalous forms of exogenous stems which must be familiar to the recollection of all botanists; and it is equally applicable to the exogenous and endogenous modes of growth, a condition which, it will be readily admitted, is indispensable to every theory of the formation of wood.

In the most recent days, it has had the advantage of being supported by M. Gaudichaud, who has made, it is said, a great number of very important and interesting observations upon the developement of stems. But, as the Memoir of this learned botanist is still unpublished, little is known of the manner in which he has treated his subject: the best account of it is given in the sixth edition of Achille Richard's *Nouveaux E'lémens de Botanique*, p. 167. So far as I am able to understand the short statement there made, the principal peculiarity in M. Gaudichaud's views consists in his assigning the growth of plants to a sort of polarity produced by the action of two opposite systems, of which the one, or *ascending*, consists of trachenchyma exclusively, the other, or *descending*, of bothrenchyma and pleurenchyma. It does not appear to which system the parenchyma is assigned; the line of demarcation between them is called the *mesocauleorhiza*. The leaf would appear to be regarded as a form of stem divided into three parts, of which the lowest is the internode from which the leaf emanates, the middle the petiole, the upper the lamina. The line of demarcation between the internode and petiole is called the *mesophytum*; that between the lamina and petiole the *mesophyllum*. It is however impossible to form any opinion concerning this theory in the absence of the evidence to prove his statements, which M. Gaudichaud is said to have produced in the Memoir laid before the Academy of Sciences in 1834.

The most important of the objections which have been taken to the opinion now under consideration are the following: — If wood were really organised matter emanating from the leaves, it must necessarily happen that in grafted plants the stock would in time acquire the nature of the scion, because its wood would be formed entirely by the addition of new matter, said to be furnished by the leaves of the scion. So far is this, however, from being the fact, that it is well known that, in the oldest grafted trees, there is no action whatever exercised by the scion upon the stock; but that, on the contrary, a distinct line of organic demarcation separates the wood of one from the other, and the shoots emitted from the stock, by wood said to have been generated by the leaves of the scion, are in all respects of the nature of the stock. Again, if a ring of bark from a red-wooded tree is made to grow in the room of a similar ring of bark of a white-wooded tree, as it easily may be made, the trunk will increase in diameter, but all the wood beneath the ring of red bark will be red, although it must have originated in the leaves of the tree which produces white wood. It is further urged, that, in grafted plants, the scion often overgrows the stock, increasing much the more rapidly in diameter; or that the reverse takes place, as when Pavia lutea is grafted upon the common horsechestnut; and that these circumstances are inconsistent with the supposition that wood is organic matter engendered by leaves. To these statements there is nothing to object as mere facts, for they are true; but they certainly do not warrant the conclusions which have been drawn from them. One most important point is overlooked by those who employ such arguments, namely, that in all plants there are two distinct simultaneous systems of growth, the cellular and the fibro-vascular, of which the former is horizontal, and the latter vertical. The cellular gives origin to the pith, the medullary rays, and the principal part of the cortical integument; the fibro-vascular, to the wood and a portion of the bark: so that the axis of a plant may be not inaptly compared to a piece of linen, the cellular system being the woof, the fibro-vascular the warp. It has also been shown by Knight and De Candolle that buds are exclusively generated by the cellular system, while roots are evolved from the fibro-vascular system. Now, if these facts are rightly considered, they will be found to offer an obvious explanation of the phenomena appealed to by those botanists who think that wood cannot be matter generated in an organic state by the leaves. The character of wood is chiefly owing to the colour, quantity, size, and distortions of the medullary rays, which belong to the horizontal system: it is for this reason that there is so distinct a line drawn between the wood of the graft and stock; for the horizontal systems of each are constantly pressing together with nearly equal force, and uniting as the trunk increases in diameter. As buds from which new branches elongate are generated by cellular tissue, they also belong to the horizontal system: and hence it is that the stock will always produce branches like itself, notwithstanding the long superposition of new wood which has been taking place in it from the scion.

The case of a ring of red bark always forming red wood beneath it, is precisely of the same nature. After the new bark has adhered to the mouths of the medullary rays of the stock, and so identified itself with the horizontal system, it is gradually pushed outwards by the descent of woody matter from above through it; but, in giving way, it is constantly generating red matter from its horizontal system, through which the wood descends, and thus acquires a colour not properly belonging to it. With regard to the instances of grafts overgrowing their stocks, or vice versâ, it seems that these are susceptible of explanation on the same principle. If the horizontal system of both stock and scion has an equal power of lateral extension, the diameter of each will remain the same; but, if one grows more rapidly than the other, the diameters will necessarily be different: where the scion has a horizontal system that developes more rapidly than that of the stock, the latter will be the smaller, and vice versâ. It is, however, to be observed, that in these cases plants are in a morbid state, and will not live for any considerable time.

Another case was, that if a large ring of bark be taken from the trunk of a vigorous elm or other tree, without being replaced with any thing, new beds of wood will be found in the lower as well as upper part of the trunk; while no ligneous production will appear on the ring of wood left exposed by the removal of the bark. Now this is so directly at variance with the observations of others, that it is impossible to receive it as an objection until its truth shall have been demonstrated. It is well known, that, if the least continuous portion of liber be left upon the surface of a wound of this kind, that portion is alone sufficient to establish the communication between the upper and lower lips of the wound; but, without some such slight channel of union, it is contrary to experience that the part of a trunk below an annular incision should increase by the addition of new layers of wood until the lips of the wound are united, unless buds exist upon the trunk below the ring. The horizontal parenchymatous system may, however, go on growing, and so form new layers.

Dutrochet mentions some cases of extraordinary longevity in the stock of Pinus Picea, after the trunk had been felled, and which he supposes fatal to the theory of wood being formed by the descent of organised matter. He says that, in the year 1836, a stock of Pinus Picea, felled in 1821, was still alive, and had formed 14 thin new layers of wood, that is, one layer each year; and another, felled in 1743, was still in full vegetation, having formed 92 thin layers of wood, or one each year. But, in reality, these cases prove nothing more than that the stock of Pinus Picea is singularly tenacious of life; for, although M. Dutrochet does not say so, there can be little doubt that these layers of wood were a parenchymatous developement of the horizontal system. (See *Comptes rendus*, iii. 748.)

Those who object to the theory of wood being generated by the action of leaves either suppose, — 1st, that liber is developed by alburnum, and wood by liber; or, 2dly, that "the woody and cortical layers originate laterally in the cambium furnished by pre-existing layers, and nourished by the descending sap. The first of these opinions appears to be that of Turpin, as far as can be collected from a long memoir upon the grafting of plants. The second is the opinion commonly entertained in France, and adopted by De Candolle in his latest published work.

The objections to the views of Turpin need hardly be stated. Those which especially bear upon the view taken by De Candolle are, that his theory is not applicable to all parts of the vegetable kingdom, but to exogenous plants only; and, that endogens and cryptogamic plants, in which there is no secretion of cambium, nevertheless have wood.

Such is the state of this subject at the time I am writing. To use the words of De Candolle, "The whole question may be reduced to this — Either there descend from the top of a tree the rudiments of fibres, which are nourished and developed by the juices springing laterally from the body of wood and bark; or new layers are developed by pre-existing layers, which are nourished by the descending juices formed in the leaves."

I would only add, that, after attentively considering the various arguments adduced in connection with this difficult question, it appears to me that the two greatest objections to the theory of Du Petit Thouars are, 1st, the existence of Dutrochet's embryo buds, already described, p. 79.; and, 2dly, M. Decaisne's statement (*Comptes rendus*, vii. 944.), that in the Beet-root, where new vascular tissue is produced, it, in the beginning, is distinct from the previously formed vascular tissue. These two points deserve to be carefully considered and re-examined.

CHAPTER VI.

OF THE LEAVES.

LEAVES are at once organs of respiration, digestion, and nutrition. They elaborate the crude sap impelled into them from the stem, decomposing its water, adding to it carbon, and exposing the whole to the action of air; and while they supply the necessary food to the young tissue that passes downwards from them and from the buds, in the form of alburnum and liber, they also furnish nutriment to all the parts immediately above and beneath them. There are many experiments to show that such is the purpose of the leaves. If a number of rings of bark are separated by spaces without bark, those which have leaves upon them will live much longer than those which are destitute of leaves. If leaves are stripped from a plant before the fruit has commenced ripening, the fruit will fall off and not ripen. If a branch is deprived of leaves for a whole summer, it will either die or not increase in size perceptibly. The presence of cotyledons, or seminal leaves, at a time when no other leaves have been formed for nourishing the young plant, is considered a further proof of the nutritive purposes of leaves: if the cotyledons are cut off, the seed will either not vegetate at all, or slowly and with great difficulty; and if they are injured by old age, or any other circumstance, this produces a languor of habit which only ceases with the life of the plant, if it be an annual. This is the reason why gardeners prefer old melon and cucumber seeds to new ones: in the former the nutritive power of the seed-leaves is impaired, the young plant grows slowly, a languid circulation is induced from the beginning; by which excessive luxuriance is checked, and fruit formed rather than leaves or branches.

Nothing can be more admirable than the adaptation of leaves to such purposes as those just mentioned. It has been already shown, in speaking of the anatomy of a leaf, that in most cases it consists of a thin plate of cellular tissue pierced by air vessels and woody tissue, and enclosed within a hollow empty stratum of cells forming epidermis. Beneath the upper epidermis the component bladders of the parenchyma are compactly arranged perpendicular to the plane of the epidermis, and have but a small quantity of air cavities among them. Beneath the lower epidermis the parenchyma is loosely arranged parallel with it, and is full of air chambers communicating with the stomates. The epidermis prevents too rapid an evaporation beneath the solar rays, and thickens when it is especially necessary to control evaporation more powerfully than usual; thus in the Oleander, which has to exist beneath the fervid sun of Barbary, in a parched country, the epidermis is composed of not less than three layers of thick-sided cells. To furnish leaves with the means of parting with superfluous moisture, at periods when the epidermis offers too much resistance, there are stomates which act like valves, and open to permit its passage: or when, in dry weather, the stem does not supply fluid in sufficient quantity from the soil for the nourishment of the leaves, these same stomates open themselves at night, and allow the entrance of atmospheric moisture, closing when the cavities of the leaf are full. In submersed leaves, in which no variation can take place in the condition of the medium in which they float, both epidermis and stomates would be useless, and accordingly neither exists. For the purpose of exposing the fluids contained in leaves to the influence of air, the epidermis would frequently offer an insufficient degree of surface. In order, therefore, to increase the quantity of surface exposed, the tissue of the leaf is cavernous, each stomate opening into a cavity beneath it, which is connected with multitudes of intercellular passages. But, as too much fluid might be lost by evaporation in parts exposed to the sun, we find that the cells of the upper stratum of parenchyma only expose their ends to the epidermis, and interpose a barrier between the direct rays of the sun and the more lax respiring portion forming the under stratum. It is not improbable, moreover, that those cells which form the upper stratum perform a function analogous to that of the stomach in animals, digest-ing the crude matter they receive from the stem; and that the lower stratum takes up the matter so altered, and submits it to the action of the atmosphere, which must enter the leaf purely by means of the stomates. Nor are the stomates and the cavernous parenchyma of the leaf the only means provided for the regulation of its functions. Hairs, no doubt, perform no mean office in their economy. In some cases these processes seem destined only for protection against cold, as in those plants in which they only clothe the buds and youngest leaves, falling away as soon as the tender parts have become hardened; but it can hardly be doubted that in many others they are absorbent organs, intended to collect humidity from the atmosphere. In succulent plants, or in such as grow naturally in shady places, where moisture already exists in abundance, they are usually wanting; but in hot, dry, exposed places, where it is necessary that the leaf should avail itself of every means of collecting its food, there they abound, lifting up their points and separating at the approach of the evening dews, but again falling down, and forming a layer of minute cavities above the epidermis, as soon as the heat of the sun begins to be perceived.

Whether or not leaves have the power of absorbing atmospheric fluid, independently of their hairs, is a matter of doubt. By some it is believed that they do possess such a power, and that absorption takes place indifferently by either the upper or under surface of the leaf, but that some plants absorb more powerfully by one surface than by the other. Bonnet found that, while the leaves of Arum, the Kidneybean, the Lilac, the Cabbage, and others, retained their verdure equally long whichever side was deprived of the power of absorption, the Plantago, some Verbascums, the Marvel of Peru, and others, lost their life soonest when the *upper* surface was prevented from absorbing; and that, in a number of trees and shrubs, the leaves were killed very quickly by preventing absorption by the *lower* surface. But others contend that Bonnet's experiments merely produced a hindrance of evaporation in some cases, and of respiration in others; and that leaves have, in fact, no power of attracting fluid. In proof of this it is urged, that, if leaves are made to float on coloured infusions, no colouring matter enters them. Considering, however, the thinness of the epidermis of many plants, and the great permeability of vegetable membrane in general, it can hardly be doubted that they do possess the power of absorption which Bonnet contends for. This seems to be proved by the effects obviously produced by a shower of rain in the summer, or by syringing the fading plants in a hothouse.

In their growth, leaves usually increase in length by addition to the base, the apex altering but little after it is originally formed. Upon this subject there is a paper by Steinheil which deserves to be consulted (*Ann. Sc.*, n. s., viii. 257.). This is only what theory would necessarily lead to, when it is considered that a leaf is an expansion of the epiphlœum (see p. 89.) and mesophlœum, its apex representing the external or ungrowing part of those cortical layers, and its base their interior or growing part.

Leaves usually are so placed upon the stem that their upper surface is turned towards the heavens, their lower towards the earth; but this position varies occasionally. In some plants they are imbricated, so as to be almost parallel with the stem; in others they are deflexed till the lower surface becomes almost parallel with the stem, and the upper surface is far removed from opposition to the heavens. A few plants, moreover, invert the usual position of the leaves by twisting the petiole half round, so that either the two margins become opposed to earth and sky, or the lower surface becomes uppermost: the former is especially the case with plants bearing phyllodia, or spurious leaves.

At night a phenomenon occurs in plants which is called their sleep: it consists in the leaves folding up and drooping, as those of the Sensitive Plant when touched. This scarcely happens perceptibly except in compound leaves, in which the leaflets are articulated with the petiole, and the petiole with the stem: it is supposed to be caused by the absence of light, and will be farther spoken of under the head of Irritability.

After the leaves have performed their functions, they fall off: this happens at extremely unequal periods in different species. In some they all wither and fall off by the end of a single season; in others, as the Beech and Hornbeam, they wither in the autumn, but do not fall off till the succeeding spring; and, in a third class, they neither wither nor fall off the first season, but retain their verdure during the winter, and till long after the commencement of another year's growth: these last are our evergreens. Mirbel distinguishes leaves into three kinds, as characterised by their periods of falling: —

1. *Fugacious*, or *caducous*, which fall shortly after their appearance; as in Cactus.

2. *Deciduous*, or *annual*, which fall off in the autumn; as the Apple.

3. *Persistent*, *evergreen*, or *perennial*, which remain perfect upon the plant beyond a single season; as Holly, common Laurel, &c.

With regard to the cause of the fall of the leaf a number of explanations have been given, which may be found in *Willdenow's Principles of Botany*, p. 336. There are, however, only two much worth recording; those of Du Petit Thouars and De Candolle.

If you watch the progress of a tree, of the Elder, for example, says the former writer, you will perceive that the lowest leaves upon the branches fall long before those at the extremities. The cause of this may be, perhaps, explained upon the following principle: — In the first instance, the base of every leaf reposes upon the pith of the branch, to the sheath of which it is attached. But, as the branch increases in diameter by the acquisition of new wood, the space between the base of the leaf and the pith becomes sensibly augmented. It has, therefore, been necessary that the fibres by which the leaf is connected with the pith should lengthen, in order to admit the deposition of wood between the bark and the pith. Now how does this elongation take place? As the bundles of fibres which run from the pith into the leaf-stalk are at first composed only of spiral vessels, it is easy to conceive that they may be susceptible of elongation by unrolling. And in this seems to lie the mystery of the fall of the leaf; for the moment will come when the spiral vessels are entirely unrolled, and incapable of any further elongation: they will, therefore, by the force of vegetation, be stretched until they snap, when the necessary communication between the branch and the leaf is destroyed, and the latter falls off.

De Candolle explains the matter otherwise and better. The increase of leaves, he says, whether in length or in breadth, generally attains its term with sufficient rapidity; the leaf exercises its functions for a while, and enjoys the plenitude of its existence; but, by degrees, in consequence of exhaling pure water, and preserving in the tissue the earthy matters which the sap had carried there, the vessels harden and their pores are obstructed. This time in general arrives the more rapidly as evaporation is more active: thus we find the leaves of herbaceous plants, or of trees which evaporate a great deal, fall before the end of the year in which they were born; while those of succulent plants, or of trees with a hard and leathery texture, which, for one cause or another, evaporate but little, often last several years. We may, therefore, in general say that the duration of life in leaves is in inverse proportion to the force of their evaporation. When this time has arrived, the leaf gradually dries up, and finishes by dying: but the death of the leaf ought not to be confounded with its fall; for these two phenomena, although frequently confounded, are in reality very different. All leaves die some time or other; but some are gradually destroyed by exterior accidents, without falling; while others fall, separating from the stem at their base, and fall at once, either already dead, or dying, or simply unhealthy.

It is probable that both these explanations are required to understand the phenomena of the fall of the leaf; and that it is neither the rupture of the spiral vessels, nor the choking up of other kinds of tissue, separately, which produce it, but the two combined; the one acting principally in some cases, and the other in others.

CHAPTER VII.

OF THE BRACTS AND FLORAL ENVELOPES.—DISENGAGEMENT OF CALORIC.

The bracts, when but slightly removed from the colour and form of leaves, no doubt perform functions similar to those of the latter organs; and, when coloured and petaloid, it may be presumed that they perform the same office as the corolla. Nothing, therefore, need be said of them separately.

With regard to the calyx, corolla and disk, I shall chiefly follow Dunal's statements in his ingenious pamphlet, *Sur les Fonctions des Organes floraux colorés et glanduleux:* 4to; Paris, 1829.

The calyx seems, when green, to perform the functions of leaves, and to serve as a protection to the petals and sexual organs; when coloured, its office is undoubtedly the same as that of the corolla.

The common notion of the use of the corolla is, that, independently of its ornamental appearance, it is a protection to the organs of fertilisation: but, if it is considered that the stamens and pistils have often acquired consistence enough to be able to dispense with protection *before the petals are enough developed* to defend them, it will become more probable that the protecting property of the petals, if any, is of secondary importance only.

Among the many speculations to which these beautiful ornaments have given birth is one, that the petals and disk are the agents of a secretion which is destined to the nutrition of the anthers and young ovules. These parts are formed in the flower-bud long before they are finally called into action; in the Almond, for example, they are visible some time before the spring, beneath whose influence they are destined to expand. In that plant, just before the opening of the flower, the petals are folded up; the glandular disk that lines the tube of the calyx is dry and scentless; and its colour is at that time dull, like the petals at the same period. But, as soon as the atmospheric air comes in direct contact with these parts, the petals expand and turn out of the calyx, the disk enlarges, and the aspect of both organs is altered. Their compact tissue gradually acquires its full colour and velvety surface; and the surface of the disk, which before was dry, becomes lubricated by a thick liquid, exhaling that smell of honey which is so well known. At this time the stamens perform their office. No sooner is that effected than they wither, the petals shrivel and fall away, the secretion from the disk gradually dries up, and, in the end, the disk perishes along with the other organs to which it appertained. If the disk of an Almond flower be broken before expansion, it will be seen that the fractured surface has the same appearance as those parts which in certain plants contain a large quantity of fæcula, as the tubers of the Potato, Cyperus esculentus, &c. This led Dunal to suspect that the young disks also contained fæcula: which he afterwards ascertained, by experiment, to be the fact in the spadix of Arum italicum before the dehiscence of the anthers; but, subsequently to their bursting, no trace of fæcula could be discovered. Hence he inferred that the action of the air upon the humid fæcula of the disk had the effect of converting it into a saccharine matter fit for the nutrition of the pollen and young ovules; just as the fæcula of the albumen is converted in germination into nutritive matter for the support of the embryo.

In support of this hypothesis, Dunal remarks that the conditions requisite for germination are analogous to those which cause the expansion of a flower. The latter opens only in a temperature above 32° Fahr., that of 10° to 30° centig. (50° to 86° Fahr.) being the most favourable; it requires a considerable supply of ascending sap, without the watery parts of which it cannot open; and, thirdly, flowers, even in aquatic plants, will not develope in media deprived of oxygen.

Thus the conditions required for germination and for flowering are the same: the phenomena are in both cases also very similar.

When a germinating seed has acquired the necessary degree of heat and moisture, it abstracts from the air a portion of its oxygen, and gives out an equal quantity of carbonic acid gas; but as one volume of the latter gas equals one volume of oxygen, it is evident that the seed is, in this way, deprived of a part of its carbon. Some changes take place in the albumen and cotyledons; and, finally, the fæcula that they contained is replaced by saccharine matter. In like manner, a flower, while expanding, robs the air of oxygen, and gives out an equal volume of carbonic acid; and a sugary matter is also formed, apparently at the expense of the fæcula of the disk or petals.

The quantity of oxygen converted into carbonic acid in germination is, *cæteris paribus*, in proportion to the weight of the seed; but some seeds absorb more than others. Theodore de Saussure has shown that exactly the same phenomenon occurs in flowers.

Heat is a consequence of germination; the temperature is also augmented during flowering, as has been proved by Theodore de Saussure in the Arum, the Gourd, the Bignonia radicans, Polyanthes tuberosa, and others.

The greater part of the saccharine matter produced during germination is absorbed by the radicle, and transmitted to the first bud of the young plant. Dunal is of opinion that the sugar of the nectary and petals is, in like manner, conveyed to the anthers and young ovules; and that the free liquid honey, which exists in such abundance in many flowers, is a secretion of superabundant fluid; it can be taken away, as is well known, without injury to the flower.

This opinion will probably be considered the better founded, if it can be shown that the disengagement of caloric and destruction of oxygen are in direct relation to the developement of the glandular disk, and also are most considerable at the time when the functions of the anthers are most actively performed.

In no plants, perhaps, is the glandular disk more developed than in Arums; and it is here that the most remarkable degree of developement of caloric has been observed. Senebier found that the bulb of a thermometer, applied to the surface of the spadix of Arum maculatum, indicated a temperature 7° higher than that of the external air. Hubert remarked this, in a still more striking degree, upon Arum cordifolium, at the Isle of France. A thermometer placed in the centre of five spadixes stood at 111°, and in the centre of twelve at 121°, although the temperature of the external air was only 66°. The greatest degree of heat in these experiments was at sunrise. The same observer found that the male parts of six spadixes, deprived of their glandular part, raised the temperature only to 105°; and the same number of female spadixes only to 86°; and, finally, that the heat was wholly destroyed by preventing the spadix from coming in contact with the air.

Similar observations were made by others, with corresponding results; but, nevertheless, as many persons attempted in vain to witness the phenomenon, it began to be doubted, especially after Treviranus added his authority to that of those who doubted the existence of any disengagement of heat. The truth of the statement of Saussure and others has lately, however, been placed beyond all further doubt, by the experiments of Adolphe Brongniart upon Colocasia odora. (*Nouv. Ann. du Muséum*, vol. iii.) From the period of the expansion of the spathe, he applied to the middle of the spadix a very delicate and small thermometer, which he fixed to its place by a piece of flannel rolled several times round it and the spadix, so that the bulb of the thermometer touched the spadix on one side; and on all others was protected by the flannel from contact with the air. All this little apparatus covered so small a portion of the spadix, that it was left in its place without interfering with the functions of that part. On the 13th of March, the spathe not being open, the flower diffused, notwithstanding, a fragrant smell. On the 14th it was open, and the odour was much increased. The emission of pollen took place on the 16th, between 8 and 10 A.M., and continued till the 18th. On the 19th the flower began to fade. From the 14th to the 19th the temperature increased daily, during the night and in the morning falling back to nearly that of the surrounding air. The maximum of elevation of temperature above that of the atmosphere occurred, —

On the 14th, at	3 P.M.	4·5° centigrade
15th,	4 P.M.	10°
16th,	5 P.M.	10·2°
17th,	5 P.M.	11°
18th,	11 A.M.	8·2°
19th,	10 A.M.	2·5°

These maxima might be almost compared to the access of an intermittent fever.

Vrolik and Vriese consider the so called Arum cordifolium of the Isle of France to be the same as the aforesaid Colocasia odora, upon whose temperature they made very numerous hourly observations in the Botanical Garden of Amsterdam, the result of which was, that the maximum of difference observed between the temperature of the spadix and that of the green-house amounted to 10° centig. (*Ann. des Sc.* vol. v. 145.) Göppert adds that plants are generally warmer than the air which surrounds them. (*Ueber warme Entwickelung in der lebenden Pflanze.* Wien, 1832.)

That these phenomena should not be observed in ordinary cases, is no proof that they do not also occur; for it is easy to comprehend that, when flowers are freely exposed to the external air, the small amount of caloric which any one may give off will be instantly dispersed in the surrounding air, before the most delicate instrument can be sensible of it; and that it is in those instances only of large quantities of flowers collected within a hollow case, like a spathe, which prevents the heat escaping when evolved, that we can hope to measure it.

From experiments of Saussure, it seems certain that the disengagement of heat, and, consequently, destruction of oxygen, is chiefly caused by the action of the anthers, or at least of the organs of fecundation, as appears from the following table: —

Names.	Duration of the Experiment.	Oxygen destroyed.		
		By the bud.	By the flower during its expansion.	By the flower in withering.
Passiflora serratifolia	12 hours.	6 times its vol.	12	7
Hibiscus speciosus	24	6	8·7	7
Cucurbita maxima, male flower	24	7·4	12	10
Arum italicum, spadix cold -	24	5 to 6		
spadix hot -	-	-	30	
24 hours after	-	-	-	5

It was also found that flowers in which the stamens, disk, pistil, and receptacle, only, were left, consumed more oxygen than those that had floral envelopes, as is shown by the following table: —

Species.	Duration of the Experiment.	Oxygen destroyed.	
		By the flowers entire.	By the usual organs only.
Cheiranthus incanus	24 hours.	11·5 times their vol.	18 times their vol.
Tropæolum majus -	24	8·5	16·3
Cucurbita maxima, male - -	10	7·6	16
Hypericum calycinum	24	7·5	8·5
Hibiscus speciosus	12	5·4	6·3
Cobæa scandens -	24	6·5	7·5

And it is here to be noticed, that those whose sexual apparatus destroyed the most oxygen have the greatest quantity of disk, and *vice versâ;* with the exception of Cobæa scandens, in which the disk is very firm and persistent, and probably, therefore, acts very slowly.

When the cup-shaped disk of the male flowers of the Gourd was separated from the anthers, the latter only consumed 11·7 times their volume of oxygen, in the same space of time which was sufficient for the destruction of sixteen times their volume when the disk remained. The spathe of Arum maculatum consumed, in twenty-four hours, five times its volume of oxygen; the termination of the spadix thirty times; the sexual apparatus 132 times, in the same space of time.

An entire Arum Dracunculus, in twenty-four hours, destroyed thirteen times its volume of oxygen; without its spathe fifty-seven times; cut into four pieces, its spathe destroyed half its volume of oxygen; the terminal appendix twenty-six times; the male organs 135 times; the female organs ten times.

The same ingenious observer also ascertained that double flowers, that is to say those whose petals replace sexual organs, vitiate the air much less than single flowers, in which the sexual organs are perfect.

Is it not then, concludes Dunal, probable, that the consequence of all these phenomena is the elaboration of a matter destined to the nutriment of the sexual organs? since the production of heat and the destruction of oxygen are in direct relation to the abundance of glandular surface, and since these phenomena arrive at their maximum of intensity at the exact period when the anthers are most developed, and the sexual organs in the greatest state of activity.

CHAPTER VIII.

FERTILISATION. — HYBRID PLANTS.

Having already, in the last chapter, explained the separate action of the stamens and pistils, I shall now confine myself to the consideration of their physical effect upon each other.

The duty of the stamens is to produce the matter called pollen, which has the power of fertilising the pistil through its stigma. The stamens are, therefore, the representatives, in plants, of the male sex, the pistil of the female sex.

The old philosophers, in tracing analogies between plants and animals, were led to attribute sexes to the former, chiefly in consequence of the practice among their countrymen of artificially fertilising the female flowers of the date with those which they considered male, and also from the existence of a similar custom with regard to figs. This opinion, however, was not accompanied by any distinct idea of the respective functions of particular organs, as is evident from their confounding causes so essentially different as fertilisation and caprification; nor was it generally applied, although Pliny, when he said that "all trees and herbs are furnished with both sexes," may seem to contradict this statement; at least, he indicated no particular organ in which they resided. Nor does it appear that more distinct evidence existed of the universal sexuality of vegetables till about the year 1676, when it was for the first time clearly pointed out by Sir Thomas Millington and Grew. Claims are, indeed, laid to a priority of discovery over the latter observer by Cæsalpinus, Malpighi, and others; but there is nothing so precise in their works as we find in the declaration of Grew, "that the attire (meaning stamens) do serve as the male for the generation of the seed." It would not be consistent with the plan of this work, to enter into any detailed account of the gradual advances which such opinions made in the world, nor to trace the progress of discovery of the precise nature of the several parts of the stamens and pistil. Suffice it to say, that, in the hands of Linnæus, the doctrine of the sexuality of plants seemed finally established, never again to be seriously controverted; for it must be admitted, that the denial of this fact, which has been since occasionally made by such men as Alston, Smellie, and Schelver, has carried no conviction with it. We know that the powder which is contained in the case of the anthers, and which is called pollen, must come in contact with the viscid surface of the stigma, or no fecundation can take place. It is possible, indeed, without this happening, that the fruit may increase in size, and that the seminal integuments may even be greatly developed; the elements of all these parts existing before the action of the pollen can take effect: but, under such circumstances, whatever may be the developement of either the pericarp or the seeds, no embryo can be formed. This universality of sexes in vegetables must not, however, be supposed to extend further than what are usually called, chiefly from that circumstance, perfect plants. In cryptogamic plants, beginning with Ferns, and proceeding downwards to Fungi, there are either no sexual organs whatever, or they are not analogous in structure to those of flowering plants.

In order to insure the certain emission of the pollen at the precise period when it is required, a beautiful contrivance has been prepared. Purkinge has demonstrated the correctness of Mirbel's opinion in 1808, that the cause of the dehiscence of the anther is its lining, consisting of cellular tissue, cut into slits, and eminently hygrometrical. He shows that this lining is composed of cellular tissue, chiefly of the fibrous kind, which forms an infinite multitude of little springs, that, when dry, contract and pull back the valves of the anthers, by a powerful accumulation of forces, individually scarcely appreciable: so that the opening of the anther is not a mere act of chance, but the admirably contrived result of the maturity of the pollen; an epoch at which the surrounding tissue is necessarily exhausted of its fluid, by the force of endosmose exercised by each particular grain of pollen.

That this exhaustion of the circumambient tissue by the endosmose of the pollen is not a mere hypothesis, has been shown by Mirbel in a continuation of the memoir I have already so often referred to. He finds that, on the one hand, a great abundance of fluid is directed into the utricles in which the pollen is developed, a little before the maturity of the latter, while, by a dislocation of those utricles, the pollen loses all organic connection with the lining of the anther; and that, on the other hand, these utricles are dried up, lacerated, and disorganised, at the time when the pollen has acquired its full developement.

Morren has made some statistical observations upon the sexual organs of Cereus grandiflorus. He found that in each flower of this plant there are about 500 anthers, 24 stigmata, and 30,000 ovules. He estimates each anther to contain 500 grains of pollen; the whole number in each flower being 250,000; so that not more than an eighth of the whole number of pollen grains can be supposed to be effective. The distance from the stigma to the ovules he computes at 1150 times the diameter of the pollen grain.

The exact mode in which the pollen took effect was for a long time an inscrutable mystery. It was generally supposed that, by some subtle process, a material vivifying substance was conducted into the ovules through the style; but nothing certain was known upon the subject until the observations of Amici and of Adolphe Brongniart had been published. It is now ascertained, that, a short time after the application of the pollen to the stigma, each grain of the former emits one or more tubes of extreme tenuity, not exceeding the 1500th or 2000th of an inch in diameter, which pierce the conducting tissue of the stigma, and find their way down to the region of the placenta, including within them the molecular matter found in the grain. These pollen tubes actually reach the ovules. Brown states he has traced them into the apertures of those of Orchis Morio, and Peristylus (Habenaria) viridis, although this great observer adds that the tubes in those plants probably do not proceed from the pollen.

Be this as it may, it is quite certain that it is absolutely necessary for the pollen to be put in communication with the foramen of the ovule, through the intervention of the conducting tissue of the style. In ordinary cases this is easily effected, in consequence of the foramen being actually in contact with the placenta. Where it is otherwise, nature has provided some curious contrivances for bringing about the necessary contact. In Euphorbia Lathyris the apex of the nucleus is protruded far beyond the foramen, so as to lie within a kind of hood-like expansion of the placenta: in all campylotropous ovules the foramen is bent downwards, by the unequal growth of the two sides, so as to come in contact with the conducting tissue: and in Statice Armeria, Daphne Laureola, and some other plants, the surface of the conducting tissue actually elongates and stops up the mouth of the ovule, while fertilisation is taking effect. Another case occurs in Helianthemum. In plants of that genus the foramen is at that end of the ovule which is most remote from the hilum; and although the ovules themselves are elevated upon cords much longer than are usually met with, yet there is no obvious means provided for their coming in contact with any part through which the matter projected into the pollen tubes can be supposed to descend. It has, however, been ascertained by Adolphe Brongniart, that, at the time when the stigma is covered with pollen, and fertilisation has taken effect, there is a bundle of threads, originating in the base of the style, which hang down in the cavity of the ovary, and, floating there, are abundantly sufficient to convey the influence of the pollen to the points of the nuclei. So, again, in Asclepiadaceæ. In this tribe, from the peculiar conformation of the parts, and from the grains of pollen being all shut up in a sort of bag, out of which there seemed to be no escape, it was supposed that such plants must at least form an exception to the general rule. But before the month of November, 1828, the celebrated Prussian traveller and botanist, Ehrenberg, had discovered that the grains of pollen of Asclepiadaceæ acquire a sort of tails, which are all directed to a suture of their sac on the side next the stigma, and which at the period of fertilisation are lengthened and emitted; but he did not discover that these tails are only formed subsequently to the commencement of a new vital action connected with fertilisation, and he thought that they were of a different nature from the pollen tubes of other plants: he particularly observed in Asclepias syriaca that the tails become exceedingly long, and hang down.

In 1831, the subject was resumed by Brown in this country, and by Adolphe Brongniart in France, at times so nearly identical that it seems to me impossible to say with which the discovery about to be mentioned originated: it will therefore be only justice if the Essays referred to are spoken of collectively, instead of separately. These two distinguished botanists ascertained that the production of tails by the grains of the pollen was a phenomenon connected with the action of fertilisation; they confirmed the existence of the suture described by Ehrenberg; they found that the true stigma of Asclepiadaceæ is at the lower part of the discoid head of the style, and so placed as to be within reach of the suture through which the pollen tubes or tails are emitted; they remarked that the latter insinuated themselves below the head of the style, and followed its surface until they reached the stigma, into the tissue of which they buried themselves so perceptibly, that they were enabled to trace them, occasionally, almost into the cavity of the ovarium; and thus they established the highly important fact, that this family, which was thought to be one of those in which it was impossible to suppose that fertilisation takes place by actual contact between the pollen and the stigma, offers the most beautiful of all examples of the exactness of the theory, that it is at least owing to the projection of pollen tubes into the substance of the stigma. In the more essential parts these two observers are agreed: they, however, differ in some of the details, as, for instance, in the texture of the part of the style which I have here called stigma, and into which the pollen tubes are introduced. Brongniart both describes and figures it as much more lax than the other tissue; while, on the other hand, Brown declares that he has in no case been able to observe "the slightest appearance of secretion, or any differences whatever in texture between that part and the general surface of the stigma" (meaning what I have described as the discoid head of the style).

I have remarked that, in Morrenia odorata, an Asclepiadaceous plant, the emission of tubes takes place to such an extent as to give the head of the stigma altogether the appearance of a mass of tow. (See *Botanical Register*, 1838, Misc. No. 129.)

The first act of fecundation in plants is, therefore, the emission of a tube by a pollen grain; but the impregnation of the ovule must necessarily be a subsequent process, in consequence of the distance which the pollen tube must travel through the stigmatic tissue before it reaches the ovule; a distance computed by Morren to amount to 1150 times its own diameter in Cereus grandiflorus. This botanist states that, in that plant and the Vanilla, impregnation does not in fact occur till some weeks after contact between the pollen and stigma has taken place.

It is, however, worthy of remark, that the first act of fecundation produces an immediate effect upon the floral envelopes. In Orchidaceæ, a flower artificially fecundated will change colour and begin to fade in twenty-four hours at the latest after this has happened, although the same flower would have remained in beauty some days if not impregnated.

It would, therefore, seem that actual contact between the pollen and the stigma is indispensable in all cases. Orchidaceous plants have, however, been thought to offer an exception; for in them nature has, on the one hand, provided special organs, in the form of the stigmatic gland and the caudicle of the pollen masses, to assist in the act of fertilisation; and on the other appears to have taken great precautions to prevent contact, by so placing the anther that it seems next to impossible for the pollen to touch the stigma unless artificially applied to it. Nevertheless, it is represented by Adolphe Brongniart, in a paper read before the Academy of Sciences at Paris, in July, 1831, that contact is as necessary in these plants as in others, and that, in the emission of pollen tubes, they do not differ from other plants. These statements have been followed up by Brown, in an elaborate essay upon the subject, in which the results that are arrived at by our learned countryman are essentially to the same effect. On the other hand, the observations of

Mr. Bauer, and the general structure of the order, seem at variance with the probability of actual contact being necessary; and, as Brown is obliged to have recourse to the supposition that the pollen of many of these plants must be actually carried by insects from the boxes in which it is naturally locked up, it would seem that the mode of fertilisation in Orchidaceæ is still unsettled. I must particularly remark that the agency of insects, to which Brown has recourse in order to make out his case, seems to be at variance with his supposition that the insect forms, which in Ophrys are so striking, and which, he says, resemble the insects of the countries in which the plants are found, "are intended rather to repel than to attract." But although such arguments are objectionable, it is, nevertheless, now certain that Orchidaceæ require that contact between their pollen and stigma should take place in order to insure fertilisation. This has been shown by Professor Morren, and has now become in gardens a matter of notoriety.

The most interesting and precise accounts of the process of impregnation yet given are those by Mr. Griffith, in the *Trans. of the Linn. Soc.* vol. xviii., with numerous explanatory plates. This excellent observer describes the impregnation of the ovulum of Santalum album as taking place by a pollen tube first coming in contact with the sac of the amnios, with which it becomes blended, without perforating the membrane. The molecular matter has at this time lost its locomotivity, and becomes aggregated into a grumous line reaching from the apex of the sac to its base. Then a globular vesicle, containing mobile granules, appears at the apex of the sac, in communication with the grumous molecular line. About the same time a distention of the base of the sac occurs, and a central cell is formed in it; by degrees the space intervening between the latter and the apex of the sac becomes cellular, and changes to a *suspensor,* having an embryo at that end which is next the base of the sac.

In Loranthus and Viscum the *ovulum is not formed till some time after the stigma is impregnated* by the pollen. Subsequently to that event, a slender sphacelated line, not previously discernible, reaches from the stigma to the interior of the ovary, which then begins to become excavated at the base; and after some time an ovule makes its appearance, having its apex directed towards the sphacelated line, and placed in contact with it. Mr. Griffith does not say that this sphacelated line is the course of the pollen tubes, nor that it causes the production of the embryo, as in the last case: but, as eventually an embryo is formed in the ovule at the end of a cellular suspensor communicating with the sphacelated line, it may be reasonably supposed that such is the fact. Mr. Griffith states that, in these two cases, the nucleus of the ovule was originally solid, and that the embryo is subsequently produced in it by an excavating process.

By some it has been thought that the molecular locomotive matter found in the interior of pollen grains represented the germs of future embryos, and that the introduction of one such molecule into an ovule was necessary in order to insure the production of an embryo. But it has been shown that the molecules are starch: upon this matter Schleiden has the following remarks: —

"It appears to me, as if the very minute chemical and microscopical researches of Fritsche on the pollen (Petersburg, 1837) have made an end of the so called pollen animalcules; for it would be contrary to the laws of animal nature, that the lively motions of these apparent infusoria should continue undisturbed after the addition of alcoholic solution of iodine (a poison that immediately kills all infusoria and animal spermatozoa), as Fritsche states to be the case, and which in many instances I have observed.

"In the Œnotheræ, however, to which Meyen has particularly referred, I have not been able to see any thing of pollen animalcules (saamenthierchens); and in these cases the contents of the pollen, *quoad solida*, also for the greatest part consists of starch. I have, at least, in Œn. Simsiana, grandiflora, and crassipes, throughout, found nothing else in the pollen besides a solution of gum and those easily recognisable small crescent-formed bodies, which Brongniart has described as pollen animalcules. These are, however, decidedly starch, and continue starch even when the pollen tube is already deep in the nucleus of the ovule. In order, however, in this case, to detect the starch, we must employ the aqueous solution of iodine, for the alcoholic solution in the first place would coagulate the gum, and in the second it colours the starch so deeply that, on account of the smallness of the grains, one can no longer judge of their colour, and as they are entirely surrounded with the gum, they may easily be supposed to be dark brown. The curvilinear motions of these so called pollen animalcules, which are said to have been observed by a good many, are very easily explained, since at least many of them, being crescent-shaped, when in motion, appear bent to the left, the right, or appear straight, according to their position to the eye."

With respect to the sexuality of plants, that at least would appear, from the facts above recited, to be established beyond the reach of controversy; but lately there has arisen in Germany a school of Botanists, at the head of which are Schleiden and Endlicher, who either deny it, or assert that the nature of the phenomenon connected with it has been misunderstood.

Schleiden states that, "if the pollen tubes be followed into the ovule, the most delicate process perhaps that occurs in botanical investigations, it will be found that usually only one, rarely a greater number, penetrates the intercellular passages of the nucleus and reaches the embryo-sac, which, being forced forwards, is pressed, indented, and becomes the cylindrical bag which constitutes the embryo in the first stage of its developement, and which consequently consists solely of a cell of parenchyma supported upon the summit of the axis. This bag is therefore formed of a double membrane (except the open radicular end), viz. the indented embryo-sac and the membrane of the pollen tube itself. In Taxus, and especially in Orchis, he has been able to withdraw out of the embryo-sac that portion of the tube which represents the first stage of the embryo, and that indeed at a tolerably advanced period.

"The tracing of the pollen tube into the interior of the embryo-sac is not so easy in all plants; because the cells of the nucleus which are arranged around the summit of the embryo-sac are very firm and opake, so that it and the pollen tube cannot be exhibited quite free. In these cases, however, three circumstances speak for the identity of the embryo with the pollen tube. 1. The constantly equal diameter of the latter, exterior to the embryo-sac, and of the former, just within it. 2. The invariable chemical similarity of their contents, shown by the reaction produced by the application of water, oil of sweet almonds, iodine, sulphuric acid, and alkalies. The general contents of the grain of pollen is starch; and this either proceeds unchanged downwards through the pollen tube, or else passes along, after being changed by a chemico-vital process into a transparent and colourless fluid, which becomes gradually more and more opake, and is coagulable by the application of alcohol: out of this, by an organising process, the cells are produced which fill the end of the pollen tube, extending, in Orchis Morio, far beyond the ovule, and thus forming the parenchyma of the embryo. 3. The identity of the embryo and the pollen tube is farther supported by the fact, that, in such plants as bear several embryoes, there is always precisely the same number of pollen tubes present as we find embryoes developed.

"The most important result of these facts is, that the sexual classification hitherto adopted in botany is directly false: for, if the ovulum be understood in physiology to represent that material foundation from which the new being becomes immediately developed, and if we term that portion of the organism in which this material commencement is deposited before it becomes developed the female organ, whilst that part which calls into action or promotes the developement of the germ by means of its potential effects is termed the male organ, it is evident that the anther of the plant is nothing but a female ovarium, and each grain of pollen the germ of a new individual. On the other hand, the embryo-sac only works potentially, determining the organisation and developement of the material foundation; and for this reason, therefore, ought to be termed a male principle, were we not to consider, perhaps more correctly (without embarrassing ourselves with lame analogies taken from the animal kingdom), that the embryo-sac merely conveys new organisable fluids by means of transudation, and thus only serves the office of nourishment.

"In the next place, the process of developement of the embryo, as already described, easily establishes the analogy of Phanerogamous plants and those Cryptogamic plants in which the spores are evident conversions of the cellular tissue of the foliaceous organs or leafy expansions; for the same part furnishes the groundwork of a new plant in both groups, and the only difference existing between the two is this; in Phanerogamæ a previous formative process in the interior of the plant precedes a period of latent vegetation, whilst in Cryptogamæ the spore (the grain of pollen) developes itself as a plant without previous preparation. Difficulties nevertheless occur here in the consideration of Mosses and Hepaticæ, and more particularly in the enigmatical Marsileaceæ. It appears to me, however, that in this last-named family especially, there still remains much to be observed."

The opinion of Endlicher is to a certain extent that of Schleiden; that is to say, he considers what we call pollen analogous to the spores of Cryptogamic plants, and consequently the anther a female organ, whose contents perform an act similar to that of germination, when they fall upon the stigma; he does not, however, with Schleiden, assign a male influence to the sac of the amnios, but he attributes that property to the stigmatic papillæ, whose moisture lubricates the grains of pollen when they fall upon them.* I know of no one else who maintains this last opinion; but it deserves to be noted that Morren observed a circulating movement (he calls it cyclosis) in the fluid filling the papillæ of Cereus grandiflorus at the period of impregnation.

One of the most curious consequences of the presence of sexes in plants is, the property the latter consequently possess of producing mules. It is well known, that, in the animal kingdom, if the male and female of two distinct species of the same genus breed together, the result is an offspring intermediate in character between its parents, but uniformly incapable of procreation, unless with one of its parents; while the progeny of varieties of the same species, however dissimilar in habit, feature, or general characters, is in all cases as fertile as the parents themselves. A law very similar to this exists in the vegetable kingdom.

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* See *Grundzüge einer neuen Theorie der Pflanzenzeigung.* Professor Wydler of Berne, also, insists upon the pollen being the female apparatus, and he denies that plants have two sexes. (*Recherches sur l'Ovule, &c., des Scrofulaires.*) These speculations have all arisen out of the undoubted fact, that the developement of spores and pollen grains takes place in the same manner, and that there is considerable resemblance in their final structure. This was, I think, first noticed by Mohl (*Ueber die Entwicklung der Sporen, &c.*), in 1833; Mirbel, in 1835, stated that there was a marvellous resemblance between these parts (*Ann. Sc.*, n.s., iv. 9.); Morren declares that the spore is organised like a grain of pollen (*Anat. des Jungermann.* p. 10.); and, finally, Wydler admits a great analogy between the formation of pollen and the spores of many foliaceous cryptogamic plants.

Two distinct species of the same genus will often together produce an offspring intermediate in character between themselves, and capable of performing all its vital functions as perfectly as either parent, with the exception of its being unequal to perpetuating itself permanently by seed; should it not be absolutely sterile, it will become so after a few generations. It may, however, be rendered fertile by the application of the pollen of either of its parents; in which case its offspring assumes the character of the parent by which the pollen was supplied. This power of hybridising appears to be far more common in plants than in animals; for, while only a few animal mules are known, there is scarcely a genus of domesticated plants in which this effect cannot be produced by the assistance of man, in placing the pollen of one species upon the stigma of another. It is, however, in general only between nearly allied species that this intercourse can take place: those which are widely different in structure and constitution not being capable of any artificial union. Thus the different species of Strawberry, of certain tribes of Pelargonium, and of Cucurbitaceæ, intermix with abundant facility, there being a great accordance between them in general structure and constitution; but no one has ever succeeded in compelling the Pear to fertilise the Apple, or the Gooseberry the Currant. And as species that are very dissimilar appear to have some natural impediment which prevents their reciprocal fertilisation, so does this obstacle, of whatever nature it may be, in general present an insuperable bar to the intercourse of different genera. All the stories that are current as to the intermixture of Oranges and Pomegranates, of Roses and Black Currants, and the like, may, therefore be set down to pure invention.

It is, nevertheless, apparently true, that *bigeners*, that is to say, mules between different genera, have in some few cases been artificially obtained. Kölreuter obtained such between Malvaceous plants; Gærtner, between Daturas and Henbane and Tobacco; Wiegman, between a Garden Bean and a Lentil; and there are other well-attested cases. But all such productions were as short-lived and sickly as they were monstrous.

As this power of creating mule plants fertile for two or three generations incontestably exists, it is not to be wondered at, that in wild nature hybrid varieties should be far from uncommon. Among the most remarkable cases are, the Cistus Ledon, constantly produced between C. monspessulanus and laurifolius; and Cistus longifolius, between C. monspessulanus and populifolius; in the wood of Fontfroide, near Narbonne, mentioned by Bentham. The same acute botanist ascertained that Saxifraga luteopurpurea of Lapeyrouse, and S. ambigua of De Candolle, are only wild accidental hybrids between S. aretioides and calyciflora: they are only found where the two parents grow together; but there they form a suite of intermediate states between the two. Gentians, having a similar origin, have also been remarked upon the mountains of Europe; and altogether about forty cases of wild reputed species of the genera Ranunculus, Anemone, Hypericum, Scleranthus, Drosera, Potentilla, Geum, Medicago, Galium, Centaurea, Stachys, Rhinanthus, Digitalis, Verbascum, Gentiana, Mentha, Quercus, Salix, and Narcissus, have been collected by Schiede, Lasch, and De Candolle; to which far too many may be added from the works of species-making botanists. It is impossible not to believe that a great proportion of the reputed species of Rosa, Rubus, and other intricate genera, have had a hybrid origin.

In a practical point of view, I am inclined to believe that the power of obtaining mule varieties by art is one of the most important means that man possesses of modifying the works of nature, and of rendering them better adapted to his purposes. In our gardens some of the most beautiful flowers have such an origin; as, for instance, the roses obtained between R. indica and moschata, the different mule Potentillæ and Cacti, the splendid Azaleas raised between A. pontica and A. nudiflora coccinea, and the magnificent American-Indian Rhododendrons. By crossing varieties of the same species, the races of fruits and of culinary vegetables have been brought to a state as nearly approaching perfection as we can suppose possible. And if similar improvements have not taken place in a more important department, namely, the trees that afford us timber, experience fully warrants the belief that, if proper means were adopted, improved varieties of as much consequence might be introduced into our forests, as have already been created for our gardens.

It is, however, to be regretted that those who occupy themselves with experiments of this kind do not confine them to woody or perennial plants which can be perpetuated by cuttings. Mule annuals have the great fault of perishing almost as soon as they are obtained, and they serve no other purpose than that of encumbering the records of science with accounts of so called species which, from their transitory existence, can never be re-examined.

These, however, are considerations which belong to Horticulture rather than to Botany. The reader who would make himself acquainted with the practical bearing of the subject should study Mr. Herbert's work on Amaryllidaceæ, p. 335. to 380.

The cause of the frequent sterility of mule plants is at present unknown. Sometimes, indeed, a deficiency of pollen may be assigned; but in many cases there is no perceptible difference in the healthiness of structure of the fertilising organs of a mule plant and of its parents. I know of no person who has attempted to prove this by comparative anatomical observations, except Professor Henslow, of Cambridge; who, in an excellent paper upon a hybrid Digitalis, investigated anatomically the condition of the stamens and pistil, both of his hybrid and its two parents, with great care and skill. The result of his enquiry was, that no appreciable difference could be detected.

CHAPTER IX.

OF THE FRUIT.

THE fruit is mechanically destined as a mere protection to the seed; it constitutes the principal part of the food, especially in winter, of birds and small animals; it is often more ornamental than the flowers themselves, and it contributes most materially to the necessities and luxuries of mankind. When ripe, it falls from the plant, and, borne down by its weight, lies on the ground at the foot of the individual that produced it: here its seeds vegetate, when it decays, and a crop of new individuals arises from the base of the old one. But, as plants produced in such a manner would soon choke and destroy each other, nature has provided a multitude of ways for their dispersion. Many are carried to distant spots by the animals which eat them: others, such as the samara, and the pappus of Compositæ, provided with a sort of wing, fly away upon the wind to seek a distant station; others scatter their seeds abroad by an explosion of the pericarp, caused by a sudden contraction of the tissue; many, falling upon the surface of streams, are carried along by the current; while others are dispersed by a variety of methods which it would be tedious to enumerate.

The fruit, during its growth, is supported at the expense of the sap generally: but most especially of that which had been previously accumulated for its maintenance. This is less apparent in perennial or ligneous plants than in annual ones, but is capable of demonstration in both. Knight has well observed, that in annual fruit-bearing plants, such as the Melon, if a fruit is allowed to form at a very early period of the life of the plant, as, for instance, in the axil of the third leaf, it rarely sets or arrives at maturity, but falls off soon after beginning to swell, from want of an accumulation of food for its support; while, if the same plant is not allowed to bear fruit until it has provided a considerable supply of food, as will be the case after the leaves are fully formed, and have been some little time in action, the fruit which may then set swells rapidly, and speedily arrives at the highest degree of perfection of which it may be susceptible. And in woody trees, also, a similar phenomenon is observable: it is well known to gardeners, that, if a season occurs in which trees in a state of maturity are prevented bearing their usual crops, the succeeding year their fruit is unusually fine and abundant; owing to their having a whole year's extra stock of accumulated sap to feed upon.

The cause of the fruit attracting food from surrounding parts is probably to be sought in the phenomenon called endosmose. All the sap that may be at first impelled into the fruit by the action of vegetation, not being able to find an exit, collects within the fruit, and, in consequence of evaporation, becomes gradually more dense than that in the surrounding tissue: it will then begin to attract to itself all the more aqueous fluid that is in communication with it; and the impulse, once given in this way to the concentration of the sap in particular points, will continue until the growth of the fruit is completed, and its tissue so much gorged as to be incapable of receiving any more food, when it usually falls off.

No one has studied the effects of fruit upon the atmosphere, and the nature of the chemical changes it undergoes, with more success than Théodore de Saussure and Bérard, an account of whose discoveries I partly translate and partly condense from De Candolle. According to the first of these original observers, "Fruits, while green, whether leafy or fleshy, act much as leaves either in the sun or in shade, and differ from those organs principally in the intensity of their action. In the night they destroy the oxygen of their atmosphere, and replace it with carbonic acid, which they partially absorb again. This absorption is generally less in the open air than under a receiver; and, their volume remaining the same, they consume more oxygen in darkness when distant from ripeness, than when they are approaching that state. If exposed to the sun, they disengage altogether or in part the oxygen which they inhaled during the night, and preserve no trace of this acid in their own atmosphere. If many fruits are detached from the plant, they thus add oxygen to air which contains no carbonic acid. When their vegetation is very feeble, or extremely languid, they vitiate the air under all circumstances, but less in the sun than in the shade. Green fruits detached from a plant, and exposed successively to the action of the sun and of darkness, change it but little or not at all either in purity or in volume. The trifling variations that may be remarked in this respect depend either upon the greater or less faculty which they have of elaborating carbonic acid, or on their composition, which is modified according to the degree of their ripeness. Thus Grapes, in a state of verjuice, appear to assimilate in small quantity the oxygen of the carbonic acid which they form in the air where they vegetate both day and night; while, on the contrary, Grapes nearly ripe give back almost entirely, during the day, to their own atmosphere, the oxygen of the carbonic acid they have formed in darkness. If there is no deception in this circumstance, which, although feeble, appears to have been constant, it marks the passage from the acid to the sweet state, by indicating that the acidity of verjuice depends upon the fixing of the oxygen of the air, and that this acidity disappears when the fruit no longer seeks for carbon in the air or in carbonic acid. Green fruits decompose, either entirely or in part, not only the carbonic acid they have produced during the night, but, in addition, such quantity as may be artificially added to their atmosphere. When this last experiment is tried with fruits which are not watery, and which, like Apples and Grapes, elaborate carbonic acid slowly, one sees that they absorb in the sun a much larger proportion of gas than the same volume of water in a similar mixture; afterwards they disengage the oxygen of the carbonic acid absorbed, and thus appear to elaborate it in their interior.

" They appropriate to themselves during their vegetation both oxygen and water, compelling the latter to lose its liquid state.

"These results are often not observable in volumes of air less than from 30 to 40 times that of the volume of the fruit, and by diminishing the heating power of the sun. If such precautions are neglected, many fruits will vitiate the air, even in the sun, by forming carbonic acid with the ambient oxygen; but, even in the latter case, the simple comparison of their effect in light, with that produced under the influence of night and darkness, demonstrates that they decompose carbonic acid."

In ripening, fruits undergo some remarkable alterations, which have been thus explained by De Candolle, in his abridgement of Bérard's observations: —

"If we examine the modifications which the flesh of fruits undergoes in ripening, we shall at first remark that their fibrous or cellular tissue (which varies very much in quantity in different species) is merely lignine: in most cases, especially in very fleshy fruits, lighter, less tough, and more easily soluble in alkaline solutions, than common lignine; but presenting characters of an opposite kind in other parts of the same fruit, such as their stones.

"The liquid which fills the flesh of succulent pericarps consists of sap placed in the intercellular passages, and of the matter contained in the cells. This liquid of the flesh, or of the fleshy endocarp, besides a great quantity of water, contains sugar, gum, malic acid, malate of lime, colouring matter, a peculiar vegeto-animal substance, and an aromatic secretion proper to each fruit: there is, moreover, in certain cases, the tartrates both of potash and of lime, as in Grapes; and citric acid in the Lemon, and even in small quantity in the Gooseberry." Bérard could find no trace of starch in watery fruits, such as Cherries, Plums, Peaches, Currants, Grapes, nor even in Pears and Apples, although it has been said to exist in them.

"A comparison of the analysis of certain fruits, before they are ripe and at that period, gives some curious results. In the first place there is a disappearance of water in a liquid state, viz., per cent, —

	" Water before ripeness.	Water at ripeness.
" Apricots	89·39	74·87
Currants	86·41	81·10
Duke Cherries	88·28	74·85
Green Gages	74·87	71·10
Melting Peaches	90·31	80·24
Jargonelle Pears	86·28	83·88

" This diminution appears to depend in part upon the fruit absorbing less water as it approaches maturity, and in part upon the combination with its tissue of a portion of the water it has received. Sugar, on the contrary, appears to be continually on the increase, as indeed the taste would tell us; thus we find, per cent,—

	" Green.	Ripe.
" Apricots (a trace when young, afterwards)	6·64	16·48
Red Currants	0·52	6·24
Duke Cherries	1·12	18·12
Green Gage Plums	17·71	24·81
Melting Peaches	0·63	11·61
Jargonelle Pears	6·45	11·52

" This sugar is sometimes in a state more or less concrete, as in the Grape, the Fig, and the Peach; sometimes in a liquid state. It seems to be formed at the expense of other matters, the proportion of which diminishes. Thus the quantity of lignine per cent is found —

	" Green.	Ripe.
" Apricots	3·61	1·86
Currants (including the seeds)	8·45	8·01
Duke Cherries	2·44	1·12
Green Gage Plums	1·26	1·11
Melting Peaches	3·01	1·21
Jargonelle Pears	3·8	2·19

" It is possible, indeed, that the lignine formed in the green fruit does not in reality diminish, but that the dilatation of the cellular tissue, and consequently the augmentation of the aqueous products, render it proportionably less, without its being absolutely so. But the gummy, mucilaginous, or gelatinous matters, appear very susceptible of changing into sugar;

thus, Couverchel found that, if we treat Apple jelly with a vegetable acid dissolved in water, we obtain a sugar analogous to that of Grapes; that the gum of Peas, placed with oxalic acid, in a temperature of 125° Réaum., changed to sugar; that gum extracted from starch, if mixed with the juice of green Grapes, rendered the latter saccharine; and finally that tartaric acid will produce the same effect by aid of heat: this is the reason why most fruits become sweet when cooked.

"Other matters offer remarkable disparities between one fruit and another: thus malic acid keeps diminishing in Apricots and Pears, augmenting in Currants, Cherries, Plums, and Peaches. Gum keeps diminishing in Currants, Cherries, Plums, and Pears, and augmenting in Apricots and Peaches. Animal matter keeps diminishing in Apricots and Plums, and increasing in Currants, Peaches, Cherries, and Pears. Lime, which never exists except in small quantity, seems generally to diminish, probably because evaporation becomes less with maturity.

"After the period which is generally called that of ripeness, most fleshy fruits undergo a new kind of alteration; their flesh either rots or *blets*.* These two states of decomposition cannot, according to Bérard, take place, except by the action of the oxygen of the air, although he admits that a very small quantity only is sufficient to cause it. He succeeded in preserving for several months, with little alteration, the fleshy fruits which were the subjects of the foregoing experiments, by placing them in hydrogen or nitrogen gases. All fruits at this extreme period of their duration, whether they decay or whether they blet, form carbonic acid with their own carbon and the oxygen of the air, and moreover disengage from their proper substance a certain quantity of carbonic acid.

"Bletting is in particular a special alteration. I have remarked, in another place, that this condition is not well characterised in any other fruits than those of Ebenaceæ and Pomaceæ; that both these natural orders agree in having the calyx adherent to the ovary, and that their fruits are austere before ripening. It would even seem, from the fruits of Diospyros, the Sorb, and the Medlar, that the more austere a fruit is, the more it is capable of bletting regularly.

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* May I be forgiven for coining a word to express that peculiar bruised appearance in some fruits, called *blessi* by the French, for which we have no equivalent English expression?

"It has been found that a Jargonelle Pear, in passing to this state, loses a great deal of water (83·88 reduced to 62·73), pretty much sugar (11·52 reduced to 8·77), and a little lignine (2·19 reduced to 1·85); but acquires rather more malic acid, gum, and animal matter. Lignine, in particular, seems, in this kind of alteration, to undergo a change analogous to that of wood in decay."

The foregoing experiments have led to the discovery, that fruits which do not require to remain on the tree may be preserved for some time, and thus the pleasure they afford us prolonged. A simple process is said to consist in placing, at the bottom of a bottle, a paste formed of lime, sulphate of iron, and water, and afterwards introducing the fruit, it having been pulled a few days before it would have been ripe. Such fruits are to be kept from the bottom of the bottle, and, as much as possible from each other; and the bottle is to be closed by a cork and cement. The fruits are thus placed in an atmosphere free from oxygen, and may be preserved for a longer or shorter time, according to their nature: Peaches, Prunes, and Apricots, from twenty days to a month; Pears and Apples for three months. If they are withdrawn after this time, and exposed to the air, they ripen well; but, if the times mentioned are much exceeded, they undergo a particular alteration, and will not ripen at all.

CHAPTER X.

OF THE SEED.

The action of the seed is confined to that phenomenon which occurs when the embryo that the seed contains is first called into life, and which is named germination.

If seeds are sown as soon as they are gathered, they generally vegetate, at the latest, in the ensuing spring; but, if they are dried first, it often happens that they will lie a whole year or more in the ground without altering. This character varies extremely in different species. The power of preserving their vitality is also variable: some will retain their germinating powers many years, in any latitude, and under almost any circumstances. Melon seeds have been known to grow when 41 years old, Maize 30 years, Rye 40 years, the Sensitive plant 60 years, Kidneybeans 100 years. Clover will come up from soil newly brought to the surface of the earth, in places in which no clover had been previously known to grow in the memory of man, and I have at this moment 3 plants of Raspberries before me, which have been raised in the garden of the Horticultural Society from seeds taken from the stomach of a man, whose skeleton was found 30 feet below the surface of the earth, at the bottom of a barrow which was opened near Dorchester. He had been buried with some coins of the Emperor Hadrian, and *it is therefore probable that the seeds were sixteen or seventeen hundred years old.*

The chemical action of seeds has been well explained by De Candolle, to whom, however, the recent observations by Edwards and Colin were unknown.

Water, heat, and atmospheric air (or at least oxygen) are the conditions without which germination cannot take place. If any one of them is abstracted, the other two are of no effect: it is, however, doubtful whether it ever happens in nature, that the act of germination takes place under conditions so simple as those; it is usually a more complicated phenomenon.

Water is the agent to which we are most in the habit of assigning the power of causing the growth of seeds; to air and heat they are generally exposed more or less, and it is by the addition of water that the two latter are popularly considered to be brought into active operation. According to De Candolle, it is a general property of seeds to absorb, during this period of germination, more than their own weight of water; but no regular proportions have been remarked, and it is probable that the respective power of different seeds depends upon the nature of the matter deposited in their tissue. The effect of water may be supposed to be that of softening the tissue, of enabling all the parts to distend, and of dissolving the soluble parts so as to render them fit to be taken into the circulation, as the young plant becomes capable of absorbing them.

Germination cannot take place *in vacuo;* nor in an atmosphere of nitrogen or hydrogen, and still less in carbonic acid; or at least, if in this latter gas some traces of germination manifest themselves, they rapidly disappear: it can only occur in free oxygen. Of this but a small proportion is really necessary; from $\frac{1}{6}$ to $\frac{1}{32}$, according to different observers. But 1 part of oxygen and 3 of nitrogen are the proportions which seem to be the most favourable, and this is not very different from the proportions in atmospheric air; viz. 1 of oxygen and 4 of nitrogen. A too large dose of oxygen weakens the young plant, by abstracting its carbon too rapidly.

Experiments show that oxygen is not absorbed by the seed, but combines with its carbon, forming carbonic acid, which is thrown off. When a seed ripens, a considerable quantity of carbon is stored up in its tissue, apparently for the purpose of enabling it to "maintain the unalterability" to which its preservation is owing. This superfluous carbon renders it scarcely soluble in water. To enable the parts to be sufficiently moistened, it is therefore necessary that the seed should be decarbonised by oxygen. This explains why Peas scarcely ripe will germinate much more rapidly than those which are fully matured; the former contain more pure water and less carbon. In fact, the effect of the abstraction, by oxygen, of the fixed carbon, is, to bring back the seed to the state in which it was, before it was provided with the means of remaining unchanged in a torpid state. The sweet taste of germinating barley is, in reality, what the seeds possessed before they were finally hardened. The destruction of oxygen, by the carbon of the seed, produces a sensible heat in germination, just as a similar cause produces a similar effect in flowers, when the fæcula of their disk is converted into sugar (see p. 331.). Hence the heat of masses of Barley which are made to germinate in darkness in order to become malt: and it can scarcely be doubted, that the change of the starch of that grain into sugar is chemically owing to the abstraction of a proportion of its carbon, and the addition of some other proportion of oxygen.

It has been asked, Whence comes the oxygen which, combining with the carbon of the seed, forms the carbonic acid expelled in germination? The usual answer is, From the air; and it is necessary that seeds should have access to the atmosphere in order to germinate. But Messrs. Edwards and Colin have shown, by recent experiments, that the oxygen of which germinating seeds make use is obtained by the decomposition of water, and not necessarily from the air. These physiologists placed Beans in water, under such circumstances that they were completely cut off from access to the air. The Beans disengaged bubbles of air from their sides in great abundance for the space of 4 days, a part of such air collecting in a receiver, but the greater part dissolving in the water. This air consisted chiefly of carbonic acid; there was also a trace of oxygen, and a small quantity of what appeared to be nitrogen. The hydrogen left after the decomposition of the water appeared to be absorbed by the seed, either wholly or in great part. This proof of the decomposition of water by the vital energies of the seed is justly stated, by the authors now quoted, to be a fact of the first importance. (*Comptes rendus*, vii. 922.)

It also appears that the carbon of seeds is lost, not only by the formation of carbonic acid, but by the production of acetic acid, during germination, a phenomenon which Messrs. Becquerel and Boussingault consider constant. (*Comptes rendus*, vi. 109.)

In the opinion of some persons, oxygen also acts as a stimulant of the vital actions of the embryo. Humboldt remarked that seeds plunged in chlorine, and taken out before the radicle appears externally, germinate more rapidly than ordinary; Cress, for instance, may thus be made to germinate in 6 hours instead of 24 or 30. He even succeeded, by this process, in bringing about germination in old seeds which appeared destitute of the power. These experiments have not, however, succeeded in all hands: in many cases it is possible that the success that is said to have attended them has been imaginary; and, as the theory upon which the action of chlorine was explained is now abandoned, one cannot avoid entertaining doubts as to the accuracy of the alleged facts.

Heat is that in which the stimulus necessary to call the vitality of seeds into action seems really to reside. No seed can germinate at a temperature so low as that of freezing; and each seems to have some one temperature more proper for it than any other, at the first dawn of its life. If, says De Candolle, the temperature is too high, germination proceeds too rapidly, and the result is weak and languishing plants, in which we cannot avoid recognising beings too much excited and badly nourished. If the temperature is too low, the excitement is not sufficient; and it often happens that the seed cannot resist the decay induced by the water it has absorbed, but not assimilated. It is between these limits that a suitable temperature for every species is to be sought.

Edwards and Colin have instituted some experiments to determine what temperature seeds can bear. They found that Wheat, Barley, and Rye could germinate at 7° centig. (44·6° Fahr.); and that grain of the same description did not apparently suffer, by being exposed for a quarter of an hour to a temperature equal to freezing mercury: such grains were afterwards placed in a proper situation, and germination took place as usual. Considering that the particles of fæcula of which seeds consist are not liable to bursting below a temperature of 75° centig. (167° Fahr.), these observers were led to ascertain how near an approach to this extreme temperature might be made, without destroying vegetable life. Seeds of various cereal and leguminous plants were placed for a quarter of an hour in water of this temperature, and they were all killed; five minutes were afterwards ascertained to suffice for the destruction of three in five. Less elevated temperatures were next experimented on. Wheat, Barley, Kidneybeans, and Flax were killed in 27½ minutes, by water at 62° centig. (143·6° Fahr.); a few grains of Rye and some Beans required a longer exposure to be destroyed. When the temperature was lowered to 52° centig. (125·6° Fahr.), most of the seeds in experiment retained their vitality; but even this was fatal to Barley, Kidneybeans, and Flax.

Fluid water has conducting powers very different from those of vapour or of dry air; it was thereupon important, to determine whether the temperature that seeds can bear is regulated by the nature of the medium in which they are exposed to it. In vapour, 75° centig. (167° Fahr.) was sufficient to destroy such seeds as were exposed; but, at 62° centig. (143·6° Fahr.), they retained their vitality, after having been under experiment for a quarter of an hour. But, in dry air, many seeds bore the temperature of 75° centig. (167° Fahr.), for a quarter of an hour, without inconvenience. Hence it appears that seeds in steam can bear 12° centig. more than in water, and in dry air 13° centig. more than in steam.

In these experiments, the action of temperature was extremely rapid. In lowering the temperature and prolonging its action, it was found that, when Wheat, Rye, and Barley were exposed for three days, in water, to a temperature of 35° centig. (95° Fahr.), four fifths of the Wheat and Rye, and all the Barley, were killed. Hence it would appear, that 35° centig. forms the highest limit of temperature which corn can bear under such circumstances. But, in sand or earth, the same grains sustained a prolonged temperature of 40° centig. (104° Fahr.) without inconvenience; at 45° centig. (113° Fahr.) a great part perished; at 50° centig. (122° Fahr.) the whole of them.

These remarkable experiments are calculated to throw great light upon the cause of the impossibility of making certain plants multiply themselves by seeds in hot countries. If Wheat, Barley, &c., cannot endure a prolonged temperature above 40° centig.; and the temperature of the soil is in some countries and soils as high as 60° centig. (140° Fahr.), as Humboldt asserts, or between 48° and 53° centig. (122° Fahr.), even in some parts of France, as Arago states; it is evident that the seeds of corn placed in such situations will perish.

Exposed to the influence of water, heat, and air, the parts of a seed soften and distend; the embryo swells and bursts its envelopes, extending the neck and the bases of the cotyledons, and finally emitting its radicle, which pierces the earth, deriving its support at first from the cotyledons or albumen, but subsequently absorbing nutriment from the soil, and communicating it upwards to the young plant. The manner in which the embryo clears itself from its integuments differs in various species: sometimes it dilates equally in all directions, and bursts through its coat, which thus becomes ruptured in every direction; more frequently the radicle passes out at the hilum, or near it, or at a point apparently provided by nature for that purpose, as in Canna, Commelina, &c. If the radicle has a coleorhiza or root-sheath, this is soon perforated by the radicle contained within it, which passes through the extremity; as in Grasses, and most monocotyledonous plants. The cotyledons either remain under ground, sending up their plumule from the centre, as in the Oak; or from the side of their elongated neck, as in Monocotyledons; or they rise above the ground, acquire a green colour, and perform the ordinary functions of leaves, as in the Radish and most plants. In the Mangrove, germination takes place in the pericarp, before the seed falls from the tree; a long thread-like caulicle is emitted, which elongates till it reaches the soft mud in which such trees usually grow, where it speedily strikes root, and separates from its parent. Trapa natans has two very unequal cotyledons: of these, the larger sends out a very long petiole, to the extremity of which are attached the radicle, the plumule, and the smaller cotyledon (Mirbel). Cyclamen germinates like a Monocotyledon: its single cotyledon does not quit the seed till the end of germination; and its caulicle thickens into a fleshy knob, which roots from its base. The Cuscuta, which has no cotyledons, strikes root downwards, and lengthens upwards, clinging to any thing near it, and performing all the functions of a plant, without either leaves or green colour. In Monocotyledons, the cotyledon always remains within the seminal integuments, while its base lengthens and emits a plumule. In Cycas, which has two cotyledons, the seminal integuments open, and the radicle escapes.

It has already been seen, that, under certain circumstances, the vitality of seeds may be preserved for a very considerable length of time; but it is difficult to say what are the exact conditions under which this is effected. We learn from experiment that seeds will not germinate if placed *in vacuo*, or in an atmosphere of hydrogen, nitrogen, or carbonic acid; but no such conditions exist in nature, and, therefore, it cannot be they which have occasionally preserved vegetable vitality in the embryo plant for many years. Perhaps the following remarks, in a work lately published by the Society for the Diffusion of Useful Knowledge, may throw some light upon the subject: —

"It may, upon the whole, be inferred from the duration of seeds buried in the earth, and from other circumstances, that the principal conditions are, 1. uniform temperature; 2. moderate dryness; and 3. exclusion of light: and it will be found, that the success with which seeds are transported from foreign countries, in a living state, is in proportion to the care and skill with which these conditions are preserved. For example, seeds brought from India, round the Cape of Good Hope, rarely vegetate freely: in this case, the double exposure to the heat of the equator, and the subsequent arrival of the seeds in cold latitudes, are probably the causes of their death; for seeds brought over land from India, and therefore not exposed to such fluctuations of temperature, generally succeed. Others, again, which cannot be conveyed with certainty if exposed to the air, will travel in safety for many months, if buried in clay rammed hard in boxes: in this manner only can the seeds of the Mango be brought alive from the West Indies; and it was thus the principal part of the Araucaria Pines, now in England, were transported from Chile. It may therefore be well worth consideration, whether, by some artificial contrivance, in which these principles shall be kept in view, it may not be possible to reduce to something like certainty the preservation of seeds in long voyages. Such, for instance, as by surrounding them with many layers of non-conducting matter, as case over case of wood; or by ramming every other space, in such cases, with clay in a dry state. These means seem more likely to answer their end, than the usual modes of putting seeds in bottles, packing them in charcoal, or surrounding them with coats of wax; all of which, it is well known, are absolutely prejudicial, instead of beneficial, to the seeds. In illustration of what we have recommended, we may add that seeds are well known to travel best in their own pods, or pericarps: may we not suppose that their vitality is preserved, in such instances, by the non-conducting quality of the air which the cavities of the fruit contain?"

CHAPTER XI.

OF THE FOOD OF PLANTS.—MANURE.

The principal part of the food of plants is derived from the earth, and is introduced into their system through the roots. The latter are, however, incapable of absorbing anything solid; fluid and gaseous matter only can pass through their spongelets. It is, perhaps, exclusively in the form of water that the nutritive matter of the soil is received by roots; not, however, of pure water, which in fact does not exist in nature, but of water holding various solid matters in solution, the most remarkable and abundant of which are, silex, lime and many of its salts, several other earths, and oxides of iron and copper.

These substances, however, although they may each perform their allotted part in the economy of vegetation, consolidating the tissue, hardening the epidermis, or assisting in depriving a plant of organs which become unhealthy and worn out, cannot be altogether considered as nutritive matter. There are, perhaps, only three forms of matter which can properly be called nutritive; carbon, water, and nitrogen.

Soil in its natural state is filled with the remains of organic bodies, which decompose, and yield nitrogen, or become converted into carbonic acid. In proportion to the abundance of these is soil fertile. Nitrogen, and the carbonic acid incessantly forming below the surface of the earth, enter freely into the roots; combining with water and such other principles as may already have been formed there, they ascend the stem, the carbonic acid decomposing to a certain extent as it passes along, and giving, apparently, its oxygen to the spiral vessels, which convey it into other parts of the system; when it reaches the leaves, it liberates its oxygen completely, and leaves its carbon to unite with the tissue of vegetation, or to enter into new combinations with water, atmospheric air, or other elements that it finds itself in contact with: whence proceed the gummy, amylaceous, resinous, oily, and other products peculiar to the vegetable kingdom. Upon this subject it has been observed by a modern writer, "that, if the roots of a plant are placed in a close vessel, in distilled water, from which carbonic acid has been carefully expelled, the plant may increase a little in size, in consequence of the decomposition of the water, and the combination of its elements with the vegetable system; but it is only when carbonic acid is added, that the plant acquires its natural vigour and rate of growth. But, if a plant is placed in solid carbon, and you water it with distilled water, it might as well be planted in powdered glass, until the carbon begins to combine with the oxygen of the air, and to form carbonic acid. Sir Humphry Davy placed a plant of Mint in water mixed with carbon in a state of impalpable powder, and he found that not a particle could enter the roots. If we look to the effects of manures, we shall find that in most cases, except when their object is to alter the state of the soil mechanically, or to act as stimulants, as is probably the case with sulphate of iron, their energy is in proportion to their capability of forming carbonic acid. Yeast, for instance, which is one of the most active manures we have, is so from possessing, beyond all other substances, the power of exciting fermentation, and thus of causing the formation of carbonic acid among the vegetable matter which lies buried in the soil.

"While, however, all experiments combine to prove that carbonic acid is the most essential of the elements upon which plants are nourished, it is necessary that the student should be aware that other species of matter are constantly taken into the system, and probably, therefore, contribute to their nutrition.

"Water is one of these. Although we know that a very large proportion of all the water absorbed by a plant is lost again by evaporation, yet the experiments of Théodore de Saussure have shown that a portion of it is actually solidified. He found that when plants are grown in a close vessel, in an artificial atmosphere, containing a little carbonic acid, the weight which the plant acquired in a given time was augmented, not only by the quantity of carbon produced by the decomposition of carbonic acid, but to a much more considerable extent, which could only be ascribed to its having fixed a considerable quantity of water; thus plants of the Periwinkle, which, in a vessel without carbonic acid, had gained 1¾ grain from water, acquired $5\frac{8}{10}$, when they were at the same time able to procure carbon. The same excellent observer has computed that, if we calculate with the utmost care all the weight which a plant can gain, by fixing carbon, by depositing earthy, saline, alkaline, and metallic matter which it borrows from the soil, by respiring oxygen, or from the soluble matter of soil, we shall not be able to account for more than a twentieth part of the real weight of such a plant. The other nineteen twentieths must, therefore, be fixed water. Whatever errors there may be in calculations of this nature, there cannot be much doubt that they are correct to so considerable an extent, as to oblige us to admit that water forms a considerable part of the solid tissue of plants; so that it would appear that, like minerals, plants have a water of crystallisation independently of their water of vegetation." It has already (p. 360.) been shown, that Messrs. Edwards and Colin have proved experimentally that plants decompose water by their vital force, fixing the hydrogen and parting with the oxygen, which combines with carbon, forming carbonic acid.

As it has been supposed that all the oxygen given off by plants is produced by the decomposition of carbonic acid, it has been inferred that, if the water which is consumed by plants is ever decomposed, it is in the formation of the various secretions which contain more oxygen (acids), or more hydrogen (oils), than water: but, as the greater part of vegetable substances, such as gum, sugar, fæcula, &c., contain oxygen and hydrogen in the same proportions as water, it has been thought that the greater part is undecomposed and simply fixed; but the experiments of Edwards and Colin, above referred to, prove the contrary.

It was formerly thought that nitrogen, or azote, has nothing to do with the nutrition of plants; and that, in those cases where it was met with, it was merely in a state of separation from the atmospheric air which had been inhaled and deprived of oxygen and carbonic acid. But its constant presence in combination with the tissue of Mushrooms and of Cruciferous plants, in gluten, and what chemists call vegetable albumen, and also in vegetable alkalies, seems a sufficiently strong proof of its contributing, in some way or other, to the nutrition of the vegetable system." And M. Boussingault has shown that it is in fact a constant element of vegetation, most concentrated in seeds, to the maturation of which it is essential, and dispersed through the other parts of the tissue. (*Comptes rendus*, vi. 105.)

Fixed as plants are to the soil, deprived of volition, and incapable of removing their highly absorbent roots from what is hurtful to them, except with extreme slowness, it appears scarcely probable that they should have any power of selecting their food; on the contrary, the facility with which they are poisoned would seem to confirm the correctness of the usual supposition. But, if roots are made to grow in coloured infusions, it is said that they take up only the colourless parts, leaving the coloured behind; and we know that if an apple tree is planted in a piece of ground in which another apple tree has been growing many years, the new plant will languish and become unhealthy, whatever quantity of manure, that is of new food, may be offered to its roots. This last fact is accounted for upon the supposition that the soil contains some peculiar principles which are necessary to the health of an apple tree, and that the old tree, having selected for its own consumption all that the soil contained, has left none behind it for the new comer; but the probability is, that this hypothesis is untenable, and that the fact is to be explained upon very different principles (see Chap. X.). It has been, however, demonstrated by Daubeny, that plants have, to a certain extent, a power of selection by their roots. He found that when barley was watered with distilled water, containing in every two gallons two ounces of nitrate of strontian, not a trace of that earth could be detected in the ashes of the plants; and when Lotus tetragonolobus was treated in a similar manner, except that only two ounces of nitrate of strontian were dissolved in ten gallons of distilled water, although the whole of that quantity was expended upon them, a minute examination demonstrated that the stems contained no trace whatever of strontian, although a small portion appeared to be present in, *or at least adherent to*, the roots. By other experiments it was ascertained, that the strontian was not in these cases first received into the system, and afterwards rejected through the roots; for when the roots of a Pelargonium were divided into two nearly equal bundles, one of which had its extremity immersed in a glass containing a weak solution of nitrate of strontian, the other in one containing pure distilled water, after the lapse of a week the water in the second glass was tested, but no strontian could be discovered in it, although a single grain in one pint would have been readily detected. Hence it appears, "that plants do possess, to a certain extent at least, a power of selection by their roots, and that the earthy constituents which form the basis of their solid parts are determined as to *quality* by some primary law of nature, although their *amount* may depend upon the more or less abundant supply of the principles presented to them from without." (*Linn. Trans.* xvii. 266.)

It must be obvious, that the *exhaustion* of soil by plants means their having consumed all the nutritive particles that it contains. Whether this means all particles that are capable of forming carbonic acid is, however, not so certain: it is highly probable that other matters are equally indispensable to the health of particular plants; as, for example, of *Corn*. Corn cannot remain in health, unless it has the power of attracting fluid silex from the earth, and of consolidating it in its epidermis. It is to be supposed, that the presence of alkaline principles in the soil is necessary to render the siliceous matter soluble; therefore, to exhaust a soil of alkaline principles would be to render it unfit for the support of Corn; and, consequently, alkaline principles may be considered nutritive in regard to Corn: and so of other things.

Again, Thaer and Boussingault both agree in considering the efficiency of manures dependent in a great measure upon their animalised nature, or their power of adding nitrogen to vegetable tissue; and, consequently, it is probable that the exhaustion of soil does not depend merely upon the destruction of carbonaceous matter, but also upon the consumption of the azotised matter contained in it. This is a most important fact to consider, in attempting to estimate the action of manures. (*Comptes rendus*, vi. 106.) M. Payen asserts that every nascent, or developing, organ contains nitrogen in abundance, and that, as a given organ developes, the azotised matter diminishes in proportion to the unazotised, which by degrees becomes predominant. (*Ibid.* vi. 132.) It is, therefore, essential for plants to be placed in such circumstances as may give them the power of assimilating nitrogen.

This diminishes the complicated nature of the theory of manures, and the seeming impossibility of reducing it to any fixed and intelligible laws. But, ignorant as we are of most of the more obscure phenomena that are attendant upon vegetable life, unacquainted with the action of a large proportion of the principles that the chemist discovers among the tissue of plants, and incapacitated by our limited means of observation from watching any except the most obvious and general properties of living vegetable matter, we cannot expect, in such a state of things, to arrive at any precise ideas as to what kind of food or stimulants exercises the most energetic and wholesome influence upon plants. I accordingly feel no surprise at the statement of a friend of mine, well known alike for his agricultural skill, his chemical knowledge, and his remarkable good sense, "that chemistry has hardly advanced the art of agriculture a single step, but that the latter remains, after all the investigations of the chemists, a mere empirical art."

Those who wish to understand the modern opinions concerning the action of manures (properly so called) should consult De Candolle's *Physiologie*, p. 1278., and the papers of Payen, Boussingault, Thaer, &c.

CHAPTER XII.

OF DIGESTION, RESPIRATION, AND SECRETION.

After the food is received into the system of a plant, it is gradually conveyed into the leaves, where it becomes decomposed or digested. It is probable that, in its passage through the stem, it undergoes some kind of decomposition, leaving a portion of its water and carbon fixed among the tissue; but it is principally in the leaves that it is altered. By the time, however, that it has arrived in these organs, it is by no means in the same state as when it entered the roots; but it becomes altered in its nature, and in its specific gravity, by the addition of what soluble matter it meets with in its progress, as has been proved experimentally by Knight.

The alteration that the fluids of plants undergo in their leaves appears to consist in parting with superfluous water by evaporation; in decomposing water and carbonic acid; and in assimilating the various matters which are left behind. The causes of these actions are believed to be, light, and the atmospheric dryness which light produces.

According to De Candolle, it is light alone to which evaporation and the suction of fluids by the roots are to be assigned. He says: " If you select three plants in leaf, of the same species, of the same size, and of the same strength, and place them in close vessels, one in total darkness, the other in the diffused light of day, and the third in the sunshine, it will be found that the first pumps up very little water, the second much more, and the third a great deal more than either. These results vary according to species and circumstances; but it uniformly happens that plants in the sun absorb more than those in diffused light, and the latter more than those in darkness; the last, however, pumping up something. If, again, we take three similar plants, and, preventing their absorption by the roots, after weighing them carefully, place them in three similar situations, we shall find that that exposed to the sun has lost a great quantity of water, that in common daylight a less amount, and that which was in total darkness almost nothing."

It is, however, to be supposed, that light is, to a certain extent, in these cases, a remote, as well as immediate, cause of evaporation: for we cannot apply solar light to plants without heating and rarefying their atmosphere. It is a well known fact, that plants perspire in a sitting-room the air of which is constantly dry, but which is but imperfectly illuminated, so much more than in the open air exposed to the direct rays of the sun, that it is impossible to keep many kinds of plants alive in such a situation.

Light is, however, to all appearance, the exclusive cause of the decomposition of carbonic acid. It was long since remarked by Priestley, that, if leaves are immersed in water and placed in the sun, they part with oxygen. This fact has been subsequently demonstrated by a great number of curious experiments, to be found in the works of Ingenhouz, Saussure, Senebier, and others. Saussure found that plants in cloudy weather, or at night, inhaled the oxygen of the surrounding atmosphere, but exhaled carbonic acid if they continued to remain in obscurity. But, as soon as they were exposed to the rays of the sun, they respired the oxygen they had previously inhaled, in about the same quantity as they received it, and with great rapidity. Dr. Gilly found that grass leaves exposed to the sun in a jar for four hours produced the following effect: —

At the beginning of the experiment there were in the jar : —		At the close of the experiment there were : —	
Of nitrogen	10·507	Of nitrogen	10·507
Of carbonic acid	5·7	Of carbonic acid	·37
Of oxygen	2·793	Of oxygen	7·79
	19·000		18·667

Heyne tells us that the leaves of Bryophyllum calycinum, in India, are acid in the morning, tasteless at noon, and bitter in the evening; Link himself found that they readily stained litmus paper red in the morning, but scarcely produced any such effect at noon. The same phenomenon is said also to occur in other plants, as Kleinia ficoides, Sempervivum arboreum, &c. This stain in the litmus paper could not have arisen from the presence of carbonic acid, as that gas will not alter blue paper, but it must have been caused by the oxygen inhaled at night. "If," says De Candolle, "two plants are exposed, one to darkness and the other to the sun, in close vessels, and in an atmosphere containing a known quantity of carbonic acid, and are removed at the end of twelve hours, we shall find that the first has diminished neither the quantity of oxygen nor of carbonic acid; and that in the second, on the contrary, the quantity of carbonic acid has diminished, while the quantity of free oxygen has increased in the same proportion. Or if we place two similar plants in closed vessels in the sun, the one in a vessel containing no carbonic acid, and the other in air which contains a known quantity of it, we shall find that the air in the first vessel has undergone no change, while that in the second will indicate an increase of oxygen proportioned to the quantity of carbonic acid which has disappeared; and, if the experiment is conducted with sufficient care, we shall discover that the plant in question has gained a proportionable quantity of carbon. Therefore, the carbonic acid which has disappeared has given its oxygen to the air and its carbon to the plant, and this has been produced solely by the action of solar light."

It is a very curious circumstance, however, that although the direct solar rays are requisite to produce a decomposition of carbonic acid in plants under experiment, yet that the most feeble diffused light of day is sufficient to produce the result more or less in a natural state. Thus we find that plants growing in wells, in rooms partially darkened, in deep forests, on the north side of high walls, and on which not a single ray of sunlight ever fell, become green, and often perform all their functions, without much apparent inconvenience. Yet De Candolle found the purest daylight, the brightest lamp-light, insufficient to bring about the decomposition of carbonic acid in an obvious manner.

It is not any kind of water in which oxygen will be evolved in the sunshine; neither boiled water, nor distilled water, nor that in which nitrogen, hydrogen, or even oxygen, has been dissolved, will produce the result. But if a small quantity of carbonic acid is dissolved in the water, the green parts, stimulated by the sun, disengage oxygen. Various ingenious means have been contrived to prove this fact, and to show that the quantity of oxygen given out is proportioned to the quantity of carbonic acid decomposed. One of the prettiest experiments is the following, by De Candolle: — He placed in the same cistern two inverted glasses, of which one (A), as well as the cistern itself, was filled with distilled water, and had a plant of Water Mint floating in it; the other glass (B) was filled with carbonic acid. The water of the cistern was protected from the action of the atmosphere by a deep layer of oil. The apparatus was exposed to the sun. The carbonic acid in the glass B diminished daily, as was obvious from the water rising in it; and at the same time there rose to the top of the glass A a quantity of oxygen, sensibly equal to the quantity of carbonic acid absorbed. During the twelve days that the experiment was continued, the Mint plant remained in good health; while, on the contrary, a similar plant, placed under a glass, filled with distilled water only, had disengaged no oxygen, and exhibited manifest signs of decomposition. The same experiment having been tried, only employing oxygen in the place of carbonic acid, no gas was disengaged in the glass that contained the Mint plant.

This is sufficient to show that the green parts of plants exposed to the sun decompose carbonic acid. By others, not less ingenious, it has been ascertained that the carbon which is the result becomes fixed in the plant itself. It has been found that Periwinkles, growing where carbonic acid had access to them, gained carbon; while similar plants, in a situation cut off from the access of carbonic acid, not only gained no carbon, but lost a part of what they previously possessed.

If the green parts of plants are placed in the dark, in a receiver full of atmospheric air, we find that the quantity of oxygen is perceptibly diminished. From this, and many other considerations, we are forced to conclude that oxygen is absorbed by plants at night. This gas does not, however, remain in the system of a plant in an elastic state, for neither the air-pump nor heat will separate it: but it appears to incorporate itself with the tissue, since solar light readily disengages it. The inference therefore is, that it is absorbed at night, and combines with the carbon already existing, forming carbonic acid, and that the latter is decomposed by the sun, as has before been shown.

It has been ascertained from other experiments, that a small quantity of carbonic acid is perpetually evolved by leaves both day and night. Some observations by Burnett, upon this subject, are detailed in the *Journal of the Royal Institution*, and have led their ingenious author to the opinion, that under the name of respiration two distinct phenomena are confounded; and that while respiration, properly so called, which consists in the extrication of carbonic acid, is incessantly in action, digestion, which is indicated by the decomposition of carbonic acid and extrication of oxygen, takes place exclusively in daylight. "Hence," he says, "are we not justified in concluding that the production of oxygen, and its converse, the formation of carbonic acid, are the unvarying results of two different functions; viz. this of respiration, that of digestion; and that both are vegetative actions dependent upon vitality? To conclude: the formation of carbonic acid is constant both by day and night, during the life of the vegetable; it is equally carried on whether in sickness or in health; it is essential to its existence for the sustentation of its irritability; for, if deprived of oxygen, and confined in carbonic acid gas, plants, like animals, quickly die. This function, which is performed chiefly by the leaves and petals, though also in a less degree by the stems and roots, like the respiration of animals, is attended with, and marked by, the conversion of oxygen into carbonic acid; it is the respiration of plants.

"Again: vegetables, at certain times and under certain circumstances, decompose carbonic acid, and renovate the atmosphere by the restoration of its oxygen; but this occasional restoration is dependent, not upon the respiratory, but the digestive, system: it in part arises from the decomposition of water, but chiefly from the decomposition of carbonic acid, absorbed either in the form of gas or in combination with water, either by the roots or leaves, or both; and here again the analogy holds good between the functions of respiration and digestion in animals and plants, for to both is carbonic acid deleterious when breathed, and to both is it invigorating to the digestive organs." (*Journal of Royal Institution*, new series, vol. i. p. 99.)

As the decomposition of carbonic acid gas is thus evidently an important part of the act of respiration, it might be supposed that to supply a plant with a greater abundance of carbonic acid than the atmosphere will usually yield would be attended with beneficial consequences. To ascertain this point several experiments have been instituted; the most important of which are those of Saussure, who found that, *in the sun*, an atmosphere of pure carbonic acid gas, or even air containing as much as sixty per cent, was destructive of vegetable life; that fifty per cent was highly prejudicial; and that the doses became gradually less prejudicial as they were diminished. From eight to nine per cent of carbonic acid gas was found more favourable to growth than common air. This, however, was only in the sun: any addition, however small, to the quantity of carbonic acid naturally found in the air, was prejudicial to plants placed in the shade.

The life of a plant seems, then, to consist in a successive diurnal decomposition and recomposition of carbonic acid. By night it vitiates the atmosphere by robbing it of its oxygen, by day it purifies it by restoring it. It is a curious question whether, by this alternation of phenomena, the vegetable kingdom actually leaves the atmosphere in its original state, or whether it purifies it permanently, giving it more oxygen than it deprives it of. Considering the great loss of oxygen produced either by the respiration of animals, or by its combination with various mineral matters, or by other means, it is to be supposed that the atmosphere would in time become so far deprived of its oxygen as to be unfit for the maintenance of animal life, if it were not for some active compensating power. This appears to reside in the vegetable kingdom; for Professor Daubeny, of Oxford, has ascertained, by experiments communicated to the British Association, that plants undoubtedly exercise a purifying influence on the atmosphere. In a letter to myself he expresses himself thus: —

"As the observations of Ellis left it in some doubt whether the balance was in favour of the purifying or the deteriorating influence upon the air which is exercised by plants during different portions of the day and night, I conducted my experiments in such a manner that a plant might be enclosed in a jar for several successive days and nights, whilst the quality of the air was examined at least two or three times a day, and fresh carbonic acid admitted as required. A register being kept of the proportion of oxygen each time the air was examined, as well as of the quantity of carbonic acid introduced, it was invariably found that, so long as the plant continued healthy, the oxygen went on *increasing*, the diminution by night being more than counterbalanced by the gain during the day. This continued until signs of unhealthiness appeared in the confined plant, when, of course, the oxygen began to decrease.

"In a perfectly healthy and natural state, it is probable that the purifying influence of a plant is much greater; for when I introduced successively different plants into the same air, at intervals of only a few hours, the amount of oxygen was much more rapidly increased, — in one instance to more than 40 per cent of the whole, instead of 20 as in the air we breathe."

Thus, the vegetable kingdom may be considered as a special provision of nature, to consume that which would render the world uninhabitable by man, and to have been so beautifully contrived that its existence depends upon its perpetual abstraction of that, without the removal of which our own existence could not be maintained.

But although this is true of green plants, it does not appear to be so of Fungi. Marcet has shown from carefully conducted experiments, "that Mushrooms, vegetating in atmospheric air, produce on that air very different modifications from those of green plants in analogous situations; in fact, that they vitiate the air promptly, either by absorbing its oxygen to form carbonic acid at the expense of the carbon of the vegetable, or by disengaging carbonic acid formed in various ways. That the modifications which the atmosphere experiences when in contact with growing Mushrooms are the same day and night. That if fresh Mushrooms are placed in an atmosphere of pure oxygen, a great part of that gas disappears at the end of a few hours. One portion of the oxygen which is absorbed combines with the carbon of the plant to form carbonic acid; whilst another part appears to be fixed in the vegetable, and to be replaced, at least in part, by nitrogen disengaged by the Mushroom. That when fresh Mushrooms remain some hours in an atmosphere of nitrogen, they modify very slightly the nature of that gas. The sole effect produced is confined to the disengagement of a small quantity of carbonic acid, and sometimes to the absorption of a very small quantity of nitrogen."

But, although the experiments of phytochemists have led to these general conclusions, it is not at all probable that the respiratory functions of plants are limited to the decomposition and recomposition of carbonic acid. It has already (page 360.) been stated that Messrs. Edwards and Colin have proved that water is decomposed in the act of germination, the *hydrogen* being fixed and the oxygen set free; and there can be little doubt that this phenomenon occurs in plants during other periods, perhaps all periods, of their vigorous growth.

Théodore de Saussure found that germinating seeds absorb *nitrogen*. It has been shown by M. Boussingault, that plants abstract from the air a quantity of this gas, which they fix in their tissue. But under what circumstances, or in what state, this element is fixed in plants is unknown at present. Nitrogen may enter directly into plants if their green parts are fit to fix it; it may pass into plants with the aerated water absorbed by the roots; and it may be possible, says M. Boussingault, that, as some suppose, there exist in the atmosphere very small quantities of ammoniacal vapour. M. Payen has also ascertained that this gas exists in abundance in plants. He finds it most plentiful in nascent organs, in those in the act of first developement, and in cambium; but he meets with it in wood generally. If a large quantity of water is passed through a stick of elder wood recently cut, the wood loses all its azotised matter, which is carried off by the water: this and some other observations satisfy him that wood generally contains a fluid charged with nitrogen; and he thence infers that the substances employed to prevent the decomposition of wood do so by acting upon the azotised matter, which they coagulate and render insoluble in water. (*Comptes rendus*, vi. 102. 132., vii. 889.) The accuracy of these statements, although opposed to the opinions formerly entertained by vegetable chemists, seems generally admitted. The cause of the importance of nitrogen to vegetation having been so long overlooked, is well explained by the committee which reported to the Institute upon M. Boussingault's observations, (*Comptes rendus*, vi. 130.) "One has been involuntarily led to suppose that nitrogen takes no part in the phenomena of vegetation, because we know that in its gaseous state it enters into combination with much difficulty. Sufficient attention has not been paid to the facility with which, on the other hand, dissolved nitrogen forms energetic combinations, nor to the pasturage of cattle on high mountains, whence there is annually abstracted, in the form of fat or milk, so much nitrogen, which nevertheless can scarcely reach such situations except by the atmosphere."

The result of the foregoing phenomena is, the formation of numerous principles peculiar to the vegetable kingdom, and the deposition of others which are foreign to plants, but which have been introduced into their system in the current of the sap. Thus are produced the silex of the Grass tribe; the sugar of the Cane, and of various fruits; the starch of Corn, Potatoes, and other farinaceous plants; the gum of the Cherry; the tannin of the Oak; and all those multitudes of alkaline, oily, resinous, and other principles, of which the modern chemist has ascertained the existence. These, belonging to the province of Chemistry rather than of Botany, need not be recapitulated here. It will be more useful to make some general observations upon the practical application of the physical laws we have been examining.

It is, however, desirable to explain that the old ideas of certain secretions of inorganic matter being formed by the vital forces of plants are altogether disproved. It has, in particular, been asserted that silex is formed by the *vis formatrix* of vegetation: but Dr. Daubeny has shown, by well conducted experiments, that siliceous matter disappears in Corn, in proportion as care is taken to deprive the medium in which Corn grows of all access to siliceous solutions. He states that, upon a general review of his experiments, the results indicate decisively a connexion between the quantity of earthy matter contained in a plant, and the readiness with which the plant is supplied with such matter from without; since, even if we confine ourselves to the examination of the parts above ground, where there can be no suspicion of any foreign admixture, it is found, as stated in the tables of experiments, that the largest amount of calcareous earth (for instance) was obtained from straw grown in Carrara marble; and so on. See, for some curious experiments on this subject, the *Transactions of the Linnæan Society*, vol. xvii. p. 262.

While, however, both experiment and theory disprove the formation of foreign matters by plants, it seems certain that silica and other earthy matters become, when they enter the tissue of a plant, organisable products, occupying in some cases a definite and invariable position in the structure, as in Grasses. There are some good observations upon this subject in *Taylor's Magazine*, vol. lxvii. p. 414., by the Rev. J. B. Reade, who states that the skeletons of vegetable tissue remain after all the carbonaceous matter is removed; and that both lime and potash enter as elements into the basis of vegetable tissue. He says he can prove that vessels are actually composed of silica, by showing that, if the latter is removed, no trace of vessel remains.

It is not, however, a necessary inference from these data, that earthy matter is indispensable to vegetable organisation, partly because Dr. Daubeny's experiments above referred to prove the contrary; and, secondly, because Göppert has shown that mineral matter artificially introduced into plants will take entire possession of them, destroying or displacing the vegetable matter, without altering their tissue or their structure. (*Comptes rendus*, iii. 656.) Moreover, the old experiments of growing plants in pure water, where they are cut off from access to foreign matter, have been repeated by M. Boussingault and M. Colin (*Comptes rendus*, vii. 889. 949.); the former found that Peas, fed with nothing but air and water, flowered and ripened seeds; the latter obtained the same result with Beans, Onions, and Polygonum tinctorium.

As light[*], if not strictly a *vis creatrix*, is the great agent by which the decomposition, recomposition, and assimilation of the juices of plants take place; and as it must be obvious that the intensity of the action of vegetable secretions, or their abundance, will depend upon the degree of their elaboration; it follows that these must be in direct proportion to the quantity of light they have been exposed to. As has been observed by the author of the article Botany, in the *Library of Useful Knowledge*, "We see in practice that the more plants are exposed to light when growing naturally, the deeper is their green, the more robust their appearance, and the greater the abundance of their odours or resins; and we know that all the products to which these appearances are owing are highly carbonised. On the contrary, the less a plant is exposed to sunlight, the paler are its colours, the laxer its tissue, the fainter its smell, and the less its flavour. Hence it is that the most odoriferous herbs are found in greatest perfection in places or countries in which the sunlight is the strongest; as sweet herbs in Barbary and Palestine, Tobacco in Persia, and Hemp in the bright plains of extra-tropical Asia. The Peach, the Vine, and the Melon, also, no where acquire such a flavour as under the brilliant sun of Cashmere, Persia, Italy, and Spain.

"This is not, however, a mere question of luxury, as odour or flavour may be considered. The fixing of carbon by the action of light contributes in an eminent degree to the quality of timber, a point of no small importance to all countries.

"It is in a great degree to the carbon incorporated with the tissue, either in its own proper form, or as resinous or astringent matter, that the different quality in the timber of the same species of tree is principally owing. Isolated Oak trees, fully exposed to the influence of light, form a tougher and a more durable timber than the same species growing in dense forests; in the former case its tissue is solidified by the greater quantity of carbon fixed in the system during its growth. Thus we have every reason to believe that the brittle Wainscot Oak of the Black Forest is produced by the very same species as produces the tough and solid naval timber of Great Britain. Starch, again, in which carbon forms so large a proportion, and which, in the Potato, the Cassava, Corn, and other plants, ministers so largely to the nutriment of man, depends for its abundance essentially upon the presence of light. For this reason, Potatoes grown in darkness are, as we say, watery, in consequence of no starch being developed in them; and the quantity of nutritious or amylaceous matter they contain is in direct proportion to the quantity of light to which they are exposed. For this reason, when orchard ground is under-cropped with Potatoes, the quality of their tubers is never good; because the quantity of light intercepted by the leaves and branches of the orchard trees, prevents the formation of carbon by the action of the sun's rays upon the carbonic acid of the Potato plant. Mr. Knight has turned his knowledge of this unquestionable fact to great account, in his application of the principles of vegetable physiology to horticultural purposes."

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[*] For some highly interesting experiments upon the effect of light passing through coloured media, in determining the appearance of the lower plants and animals, see Morren's *Essais sur l'Hétérogénie dominante ;* Liège, 1838.

That the intensity of light does in fact vary most materially in different climates, is a matter of inference from the difference of temperature. But it never has been actually measured, to my knowledge, by any one except Herschel, who, in a communication made to the *Athenæum* newspaper of April 25. 1835, speaks of an instrument called an actinometer, which he finds extremely sure and uniform in its indications. This instrument gives the force of sunshine at the Cape of Good Hope as 48·75°, while ordinary good sunshine in England is only from 25° to 30°.

The principal part of the secretions of plants is deposited in some permanent station in their system; as in the roots of perennials, and the bark and heartwood of trees and shrubs. It appears, however, that they have, besides this, the power of getting rid of superfluous or deleterious matter in a material form. In the Limnocharis Plumieri there is a large pore terminating the veins of the apex of the leaf, from which water is constantly distilled. The pitchers of Nepenthes, which are only a particular kind of leaves, secrete water enough to fill half their cavity. But, besides this more subtle fluid, secretions of a grosser quality take place in plants. The honey dew, which is so often attributed to insects, is one instance of the perspiration of a viscid saccharine substance; the manna of the Ash is another; and the gum ladanum that exudes from the Cistus ladaniferus is a third instance of this kind of perspiration. It is, however, by the roots, that the most remarkable secretions are voided.

It has long been known that some plants are incapable of growing, or at least of remaining in a healthy state, in soil in which the same species has previously been cultivated. For instance, a new apple orchard cannot be made to succeed on the site of an old apple orchard, unless some years intervene between the destruction of the one and the planting of the other; in gardens, no quantity of manure will enable one kind of fruit-tree to flourish on a spot from which another tree of the same species has been recently removed; and all farmers practically evince, by the rotation of their crops, their experience of the existence of this law.

Exhaustion of the soil is evidently not the cause of this, for abundant manuring will not supersede the necessity of the usual rotation. The celebrated Duhamel long ago remarked that the Elm parts by its roots with an unctuous dark-coloured substance; and, according to De Candolle, both Humboldt and Plenck suspected that some poisonous matter is secreted by roots; but it is to Macaire, who, at the instance of the first of these three botanists, undertook to enquire experimentally into the subject, that we owe the discovery that the suspicion above alluded to is well founded. He ascertained that all plants part with a kind of fæcal matter by their roots; that the nature of such excretions varies with species or large natural orders: in Cichoraceæ and Papaveraceæ he found that the matter is analogous to opium, and in Leguminosæ to gum; in Gramineæ it consists of alkaline and earthy alkalies and carbonates, and in Euphorbiaceæ of an acrid gum-resinous substance. These excretions are evidently thrown off by the roots, on account of their presence in the system being deleterious; it was also found, by experiment, that plants artificially poisoned parted with the poisonous matter by their roots. For instance, a plant of Mercurialis had its roots divided into two parcels, of which one was immersed in the neck of a bottle filled with a weak solution of acetate of lead, and the other parcel was plunged into the neck of a corresponding bottle filled with pure water. In a few days the pure water had become sensibly impregnated with acetate of lead. This, coupled with the well-known fact that plants, although they generate poisonous secretions, yet cannot absorb them by their roots without death, as, for instance, is the case with Atropa Belladonna, seems to show that the necessity of the rotation of crops is more dependent upon the soil being poisoned than upon its being exhausted.

While oxygen and carbon are thus essential to vegetation when not administered in excess, almost all other gases are more or less deleterious.

Although *nitrogen* is, as has already been shown, an important and constant element in vegetation when dissolved or obtained by the decomposition of the atmosphere, yet in a pure gaseous state it seems incapable of affording any support to the developement of plants, as proved by Théodore de Saussure, who found that, five days after immersion in pure nitrogen, the buds of poplars and willows were in a state of decay. But he inclined to ascribe the apparent incapability of leafy plants to absorb nitrogen to the artificial conditions under which the experiments were conducted. And this is probable, considering the nature of modern discoveries with respect to the action of nitrogen in vegetation.

Pure *hydrogen* seems to act unequally upon vegetation. Saussure found that a plant of Lythrum Salicaria, after five weeks, had caused no alteration in a known volume of hydrogen by which it was surrounded, and had not itself expeperienced any apparent effect. Sir Humphry Davy, however, states that some plants will grow in an atmosphere of hydrogen, while others quickly perish under such treatment.

Drs. Turner and Christison found that so small a quantity as $\frac{1}{10000}$ of *sulphurous acid gas*, a proportion so minute as to be imperceptible to the smell, was sufficient to destroy the life of leaves in forty-eight hours. The same observers state, in an excellent paper in *Brewster's Journal* for January, 1828, the effects of other gases upon plants. I much regret that want of space prevents my giving their experiments in detail: the results, which are as follows, are very important. *Hydrochloric*, or *muriatic*, *acid gas* was found to produce effects not inferior, — nay, even superior, — to those of the sulphurous acid. It was found that so small a quantity as a fifth of an inch, although diluted with 10,000 parts of air, destroyed the whole vegetation of a plant of considerable size in less than two days. " Nay, we afterwards found that a tenth part of a cubic inch, in 20,000 volumes of air, had nearly the same effects. In twenty-four hours the leaves of a laburnum were all curled in on the edges, dry and discoloured; and, though it was then removed into the air, they gradually shrivelled and died. Like the sulphurous acid, the hydrochloric acid gas acts thus injuriously in a proportion which is not perceptible to the smell. Even a thousandth part of hydrochloric acid gas is not distinctly perceptible; a ten-thousandth made no impression on the nostrils whatever, although great care was taken to dry thoroughly the vessels used in making the mixtures.

" *Chlorine* may be expected to have the effects of hydrochloric acid gas; and so indeed it has, but they appear to be developed more slowly. Two cubic inches, in two hundred parts of air, did not begin to affect a mignonette plant for three hours; half a cubic inch, in a thousand parts of air, did not injure another in twenty-four hours: but when the plants did become affected, the same drooping, bleaching, and desiccation were observed.

" *Nitrous acid gas* is probably as deleterious as the sulphurous and hydrochloric acid gases. In the proportion of a hundred and eightieth, it attacked the leaves of a mignonette plant in ten minutes; and half a cubic inch, in 700 volumes of air, caused a yellowish green discolouration in an hour, and drooping and withering in the course of twenty-four hours. The leaves were not acid on the surface.

" The effects of *sulphuretted hydrogen* are quite different from those of the acid gases. The latter attack the leaves at the tips first, and gradually extend their operation towards the leafstalks; when in considerable proportion, their effects began in a few minutes; and if the quantity was not great, the parts not attacked generally survived, if the plants were removed into the air. The sulphuretted hydrogen acts differently; two cubic inches, in 230 times their volume of air, had no effect in twenty-four hours. Four inches and a half, in eighty volumes of air, caused no injury in twelve hours; but, in twenty-four hours, several of the leaves, without being injured in colour, were hanging down perpendicularly from the leafstalks, and quite flaccid; and, though the plant was then removed into the open air, the stem itself soon began also to droop and bend, and the whole plant speedily fell over and died. When the effects of a large quantity, such as six inches in sixty times their volume, were carefully watched, it was remarked that the drooping began in ten hours, at once from the leafstalks; and the leaves themselves, except that they were flaccid, did not look unhealthy. Not one plant recovered, any of whose leaves had drooped before it was removed into the air.

" The effects of *ammonia* were precisely similar to those of sulphuretted hydrogen just related, except that after the leaves drooped they became also somewhat shrivelled. The progressive flaccidity of the leaves; the bending of them at their point of junction with the footstalk, and the subsequent bending of the stem; the creeping, as it were, of the languor and exhaustion from leaf to leaf, and then down the stem, were very striking. Two inches of gas, in 230 volumes of air, began to operate in ten hours. A larger quantity and proportion seemed to operate more slowly.

" *Cyanogen* appears allied to the two last gases in property, but is more energetic. Two cubic inches, diluted with 230 times their volume of air, affected a mignonette plant in five hours; half a cubic inch, in 700 volumes of air, affected another in twelve hours; and a third of a cubic inch, in 1700 volumes of air, affected another in twenty-four hours. The leaves drooped from the stem without losing colour; and removal into the air, after the drooping began, did not save the plants.

" *Carbonic oxide* is also probably of the same class, but its power is much inferior. Four cubic inches and a half, diluted with 100 times their volume of air, had no effect in twenty-four hours on a mignonette plant. Twenty-three cubic inches, with five times their volume of air, appeared to have as little effect in the same time; but the plant began to droop when it was removed from the jar, and could not be revived.

" *Olefiant gas*, in the quantity of four cubic inches and a half, and in the proportion of a hundredth part of the air, had no effect whatever in twenty-four hours.

" The *protoxide of nitrogen*, or *intoxicating gas*, the last we shall mention, is the least injurious of all those we have tried; indeed, it appears hardly to injure vegetation at all. Seventy-two cubic inches were placed with a mignonette plant, in a ar of the capacity of 500 cubic inches, for forty-eight hours; but no perceptible change had taken place at the end of that time."

Göppert has also found that *hydrocyanic acid* in a gaseous state is fatal to vegetation. Numerous experiments upon the action of this and other substances deadly to plants are to be found in this author's dissertation, *De Acidi Hydrocyanici Vi in Plantas*: Vratislav. 1827.

CHAPTER XIII.

OF THE CIRCULATION.

Plants have no circulation of their fluids analogous to that of the blood in the higher animals; that is to say, departing and returning incessantly from and to one common point. But that their fluids have a motion may be inferred from their nature; and that it is often of extreme rapidity is proved by the great quantity of water which they perspire; all of which must be replenished by aqueous particles in rapid motion along the tissue from the roots. A young vine leaf, in a hot day, perspires so copiously, that, if a glass be placed next its under surface, it is presently covered with dew, which, in half an hour, runs down in streams. Hales computed the perspiration of plants to be seventeen times more than that of the human body. He found a sunflower lose one pound four ounces, and a cabbage one pound three ounces, a day by perspiration. By some contrivances of glass tubes and a mercurial apparatus, he found means to measure the force of suction in particular trees, which will of course be in proportion to the amount of evaporation; and he ascertained that an apple branch 3 feet long would raise a column of mercury 5¾ inches in half an hour; a nonpareil branch 2 feet long, with 20 apples on it, 12 inches in 7 minutes; and the root of a growing pear tree 8 inches in 6 minutes. In short, he computed that the force of motion of the sap is sometimes five times greater than that which impels the blood in the crural artery of the horse. Guettard asserts that the young shoots of Cornus mascula lose twice their own weight a day. This perspiration is regulated in part by the number of the stomates, and in part by the thickness of the epidermis: hence evergreens, in which the stomates are small, and less numerous than in deciduous or herbaceous plants, and the epidermis thicker and harder, perspire much less than other plants.

M. Biot has succeeded in injecting the red colouring matter of Phytolacca decandra into the flowers of white hyacinths. He learned from a paper by De la Baisse, in *Recueil des Prix de l'Académie de Bordeaux*, vol. iv., that the juice of this plant is free from all the objections usually found to the red colouring matter used for such experiments, and that he had succeeded in injecting it into all sorts of white flowers, and even green leaves. Biot found, however, that although he did in many cases succeed, yet the practice was attended with peculiar difficulties. Many plants refused the injection altogether, others took it up with rapidity. A few minutes sufficed to vein with a multitude of red lines all the petals of a white monthly rose, while a white musk rose was not affected. He even found that the flowers of the same species resisted the entrance of the colouring matter in an unequal degree.

That a general motion of fluids really exists in plants is, therefore, undoubted. It is most rapid in the spring and early summer, and most languid in winter; but never actually suspended, unless under the influence of frost. This has been demonstrated by Biot, who, by means of an apparatus described in the *Institut* Newspaper, succeeded in measuring the power of motion in the sap of plants, in witnessing the phenomena which regulated it, and in determining the causes that brought them about.

" Atmospherical circumstances," he says, " and especially the absence or presence of solar light, exercise a marked influence upon these phenomena; but it is exceedingly difficult to ascertain their exact nature. Nevertheless, among them is one, the effects of which are so constant and undoubted, that they appear susceptible of being defined. This consists in the sudden appearance of frost immediately succeeding mild weather, and lasting for some time. Mild weather either favours or brings about the ascent of the sap; but, if a sudden frost supervenes, it seizes upon the part of the trunk swollen with fluid, and forces the latter to fall back again : should the frost continue and increase in severity, the earth at the foot of the tree freezes; and, whether at that time the roots are mechanically compressed by it, or whether the duration of the cold causes contraction by a vital action, the roots commence causing a considerable discharge of fluid from the lower part of the apparatus. This goes on night and day, except when the pipes to carry off the sap are frozen. As soon as a thaw comes on and the earth is relaxed, the roots, emptied of their juices, find themselves below their point of saturation; they then emit nothing, but on the contrary absorb the descending juices. I satisfied myself of this not only by my apparatus, but in sawing through the trunk of a large poplar tree, a yard from the ground. The surface of the section of the stump was dry, but that of the trunk itself dripped with water."

The motion of the sap appears to be of two kinds; 1. *general*, and 2. *special:* these must be carefully distinguished. The former is what has been alluded to in the preceding observations; the latter is altogether of a different nature, and exists in two entirely different conditions, generally confounded with each other, till distinguished by Professor Schultz. Of these, the first is called *Rotation*, the latter *Cyclosis;* the two are said never both to occur in the same species.

Of Rotation.

This kind of motion is confined to plants of a low organisation, but not entirely to flowerless or cellular families. It, however, forms for Professor Schultz an important physiological means of separating the vegetable kingdom into two primary classes, namely, *Homorgana* and *Heterorgana:* the former of which, consisting wholly or in great measure of cellular tissue, contains all the cellular flowerless, and some flowering plants of a low organisation; the latter all the higher flowering plants, and the vascular flowerless. It consists in a special circulation of the fluid contained in the interior of each cell, and is always so limited; the rotation in one cell never interposing or mixing with that in another cell. The rotating sap of such plants is said by Schultz to have the power of absorbing coloured fluids, while the cinenchymatous vessels, in which cyclosis goes on, either do not take up any coloured fluid, or, at least, not till they receive it in an altered state from other forms of tissue.

Corti, in 1774, Fontana, L. C. Treviranus, and especially Amici, made the earliest observations upon rotation. It was found that if a portion of Nitella flexilis, or even of the crustaceous Charas, their opake cuticle being first scraped away, be examined, a current of sap will be distinctly seen in each cellule, setting from joint to joint, flowing down one side and returning up the other, without any membrane intervening to separate the opposing currents; each cellule has a movement of its own, independent of that of the cellules above and below it; sometimes the movement stops, and then goes on again after a brief interval; if a cellule is divided into two by a ligature passed round it, a separate movement is seen in each of the divisions; this motion is rendered distinctly obvious by the numerous minute green granules which float in the transparent fluid, and which follow the course of the currents.

The observations of Amici have been verified and much extended by subsequent investigations.

Among other things, it has been ascertained that in Nitella the currents have always a certain relation to the axis of growth, the ascending current uniformly passing along the side of the cell most remote from the axis, and the descending current along the side next the axis.

Mr. Varley considers (*Trans. Soc. Arts*, xlix. p. 20.) that, in addition to the principal current, which he finds setting up one side and down the other within the green interior granular sac of each joint of Chara, there are two others, of which one takes place between the side of the interior sac and the side of the outer transparent coating, the other current is said to occur in the centre of the interior cell, and to be very sluggish.

A further and very detailed examination of the Chara fragilis has been made by M. Dutrochet, the general results of which are to be found in the *Ann. des Sciences*, n. s., vol. ix. p. 73. It appears from them, among other things, that experiments, expressly instituted by M. Becquerel, show the motion *not* to be owing to a voltaic action of the green globules lining the cells, nor to any known form of electrical agency, but to vital force; and, also, that the rapidity of the movement is increased by an elevated, and diminished by a lowered, temperature, the mean rate of motion of the swimming granules being a millimetre ($\frac{443}{1000}$ of a line) in 35 or 36 seconds.

Similar motions have been seen in several other plants. In the cells of Hydrocharis Morsus-Ranæ the fluid has been observed to move round and round their sides in a rotatory manner, which, however, has not been seen to follow any particular law.

Pouchet and Meyen (*Ann. Sc.*, n. s., iv. 257.) have remarked it in the longer cells of the stem of Zannichellia palustris, and the latter in Vallisneria, Stratiotes, Potamogeton, and the radical hairs of Marchantia. It may be distinctly seen in Equisetum. According to Schultz (*Arch. Bot.* ii. 425.), it is also visible in Podostemaceæ, Ceratophyllum, Naiadaceæ, Zosteraceæ, Lemna, Mosses, Hepaticæ, Lichens, Algæ, and Fungi. The rotation in Vallisneria canadensis is most beautiful. In large cylindrical cells filled with a transparent fluid, there float large brilliantly green spherules, which rotate up one side and down another with a slow motion, sometimes crowding together, sometimes distant, and occasionally stopping. There is, moreover, among the woody tubes, a more rapid movement of very minute oval bodies, which goes on in lines upwards and downwards.

According to Meyen, the granules seen moving in the rotating currents are of different kinds (*Ann. Sc.*, n. s., iv. 261.), the larger being grains of starch, others vesicles slightly coloured by chlorophyll, and some being drops of oil. I find but little trace of fæcula in Vallisneria, tincture of iodine chiefly producing a brown colour upon the granules, but here and there a blue nucleus was visible; perhaps the result would have been different, had the watery infusion of iodine been employed.

Of Cyclosis.

At page 35. a particular kind of tissue, called cinenchyma, or vessels of the latex, has been mentioned. It is in this description of tissue that the phenomenon of cyclosis takes place. The detailed statements of Professor Schultz of Berlin, to whom, almost exclusively, we owe all that we know with precision concerning this important discovery, were communicated to the Academy of Sciences of Paris, in September, 1829; they were reported upon in September, 1830, by Messrs. Cassini and Mirbel, with a recommendation that the memoir, and the beautiful drawings accompanying it, should be published. This, however, was not done, but, in the year 1833, the great Montyon prize in physics was awarded to M. Schultz, for a new memoir upon cyclosis, upon the report of Messrs. Auguste de St. Hilaire, Dutrochet, Adr. de Jussieu, Becquerel, and De Mirbel. Owing, however, to some unexplained cause, the memoir is still, March, 1839, unpublished, although its appearance is said to be close at hand. Under these disadvantageous circumstances, it is not surprising that so many errors should have been committed concerning cyclosis: some, among whom I am to be numbered, doubting its existence as a peculiar system of motion; most writers confounding it with rotation; and a few describing it, but, according to its discoverer, with but little attention to precision. I confess that, until I enjoyed the advantage of examining it with Professor Morren and Professor Schultz himself, I had no exact ideas concerning it. In the following statement, I have endeavoured to confine myself to the explanations given by Professor Schultz himself, with one or two exceptions.

1. The phenomenon of cyclosis *consists* of a motion of fluid called *latex*, usually more or less milky, but often transparent, which conveys granular matter through a plexus of reticulated vessels, in all directions; when the vessels are parallel and near each other, the currents rise in some and fall in others, but, in connecting or lateral vessels, the currents are directed from right to left, or the reverse, according to no apparent rule. The contiguous rows of vessels anastomose from place to place; which produces a permanent interruption of the rising and falling currents. In order to enable a circulating motion to take place, it is necessary that the system of vessels should be reticulated, as takes place in the

peripherical vascular system of animals. The vessels contract and become so small as to be invisible, they then fill themselves again, enlarge, and re-establish the communication which had been interrupted. It often happens that when strong currents are formed, the weak ones disappear. If a current is about to stop, it may be seen to oscillate a moment both in front and rear. If the globules are amassed in a particular place, an obstruction takes place, and the fluid part of the latex is no longer capable of passing along. If we take a thin slice of bark, or better still, certain entire organs, very thin, transparent, and young, but fully formed, in which the latex has an abundance of globules, it is often easy to observe a translation of fluid, and to appreciate its rate of motion, by the time which the globules take in moving a certain space. In cases where the motion of cyclosis cannot be actually seen in the vessels, it may be inferred from the following fact. When the two ends of a stem containing milk are cut through, the latex is seen to run out at both ends of the fragment, which proves that there must be both an ascending and descending current: the same phenomenon is visible in plants having a colourless latex; therefore there must be a motion of ascent and descent in them also.

2. It *occurs* in the greater part of monocotyledonous and dicotyledonous plants, and the vessels in which it takes place, are so generally in connection with spiral vessels, that the presence or absence of the one is usually accompanied by that of the other. The situation of the vessels in which it is found is, in the root, stem, petiole, peduncle, flower, &c. The system of vessels, in the form of a delicate network, surrounds the cells, and even traverses their interior, in the most diverse directions. In the stems of monocotyledons, cyclosis occurs in the woody bundles, as also in those dicotyledons which have their wood in like manner separated into distinct cords. But, in the stems of dicotyledons where the wood is disposed concentrically, the vessels of the latex are either placed singly, in the parenchyma of the bark; or, which is most common, they either form a continuous envelope around the wood, or bundles arranged circularly, or

even scattered cords. Vessels of latex may even be found in the pith. Schultz finds them in communication with the curious glands which in Nepenthes line the pitcher, and secrete the water found therein. In the form of capillary vessels (vasa contracta), they are very commonly present in hairs, where they form a most delicate plexus. It is, however, difficult to prove that the streams visible in hairs are really ramifications of cinenchyma, and Meyen has even denied their existence, upon which M. Schultz says with some asperity: "Wonderful enough, he has had them before his eyes, everywhere, in the fine anastomosing streams in which the sap circulates in the cells, without recognising them. These vessels pass through and round the different organs, particularly the cells of the secreting organs, like a fine spider's web, and are visible in many plants, for example in the species of Caladium and Arum, even after maceration."

3. The latex is a highly elaborated and highly organised juice, which is not formed immediately from the fluid nutrient matter absorbed from without. It is usually viscid, insoluble in water, often opake, coloured white, yellow, red, brown, and is also often transparent and colourless; differences that result from the nature of the organised globules it contains, which, according to M. Schultz, *constitute the living part of the latex.* These globules have an oscillating motion, and, like the globules of blood, they coagulate, and the liquid part becomes transparent. In many plants which, when old, have a milky latex, it is colourless when they are young; this depends upon the degree of concentration of the latex. Upon exposure to the air, latex separates into a *coagulum* of a tenacious elastic quality, and a *serum,* the former being sometimes analogous to caoutchouc. This property is not found in any other vegetable secretions. If we consider the organisation of the latex, the globules it contains, its property of coagulating and separating into serum and a sort of fibrine, we are tempted to believe that there exists a considerable analogy between it and the blood of animals. By these marks the latex may be known from ethereal oil, resin, gum, and other secretions sometimes found in the interior of parenchyma, and which are always trans-

parent and destitute of globules. Nevertheless, Link has unaccountably confounded with cinenchyma the turpentine vessels of Coniferæ. (*Elementa*, ed. 2., i. 196.)

4. The latex itself *originates* in the sap, which rises by the tissue of the wood, and introduces itself into the foliaceous organs, thence, after being elaborated, passing into the bark, where it is deposited in the vessels in its mature form. De la Baisse caused a Euphorbia to pump up water coloured red; the liquid ascended in the wood, reached the leaves, tinged the latex, and the colour spread from above downwards in the bark: but M. Schultz only twice succeeded, after many attempts, at obtaining this result.

5. The *function* of the latex is to nourish the tissue among which it is found. Increase in the layers of wood and bark may be arrested, if by ligatures, or cutting off annular portions of the bark, the afflux of nutritious particles from above downwards is stopped. Now the latex is the only one of the fluids in the bark which can have a progressive motion, and it is therefore it which furnishes nutrition. Upon robbing Asclepias syriaca of a great quantity of its milk, it ceased to bear fruit, but it sustained no inconvenience upon merely losing its sap. In fact, the loss of only small quantities of latex injures plants very much. It is the phenomenon of *autosyncrisis* and *autodiacrisis* (attraction and repulsion of the globules) which produces assimilation and nutrition. In consequence of autodiacrisis, the molecules of latex escape through the sides of its vessels, to be conveyed to the parts requiring nutriment; while, on the contrary, autosyncrisis brings about the assimilation of the nutritious matter. In proof of which, it is found that the distribution of latex is most abundant in those parts where the greatest increase ought to take place, and that the rapidity of the cyclosis is greatest at the periods of developement, the temperature remaining the same.

6. The *cause* of the motion may be assigned to *heat;* for, when Acer platanoides was exposed to a temperature of —18° to 24° centig. (—2° to 11° Fahr.), the latex ceased to move, but the motion was re-established when it was brought into a warm room: to *endosmose;* for water will sometimes cause a

renewal of motion when it has stopped: to *light;* because that agent determines the direction of growth: to *contraction*, which is the effect of irritability; not however, a contraction with successive pulsations, as in arteries, but by a simultaneous action throughout the whole length of the vessel, whose latex is thus brought into a state of powerful tension. Contraction, however, cannot be the first cause of the motion, for it is not even sufficient to change the direction of the currents. When a vessel has been cut through at both ends, it has discharged all its contents by that end to which the current had been directed, and not by the other. But these are to be regarded as secondary causes only; the essential cause is the perpetual oscillation of the globules. They have an incessant tendency to unite and to separate, without the one tendency ever overcoming the other; and, as the organic (molecules) elements of vessels are of the same nature as the globules of latex, it follows that the walls of the vessels, and the globules they contain, have the same tendency to approach and retreat, as the globules themselves have with respect to each other. As this motion of coming and going takes place in a determinate direction, it necessitates and regulates the progressive motion of the latex. This law, says M. Schultz, is, for the physiologist, what attraction and repulsion are for the investigator of physical actions; it is final, and explains phenomena because it is itself placed beyond the reach of explanation. [This opinion is strongly objected to by the committee who reported upon M. Schultz's paper.]

7. Cyclosis is *analogous* to the motion of the blood in the lower animals, such as Nephelis vulgaris, Planarias, Nais proboscidea, and Diplozoon paradoxum; or in the fœtus of a fowl, before the heart is formed, when, as Malpighi and Wolff have shown, the blood moves spontaneously in the vascular apparatus. Nevertheless, although there is in plants no heart, or centre of circulation, it appears that there are certain foci, concerning which M. Schultz speaks thus (*Comptes rendus*, vi. 583.): — In Commelina cœlestis there is a bundle of laticiferous vessels, which are very delicate and filamentous, compact and united in the form of a net with

very long meshes, in which are perceptible currents of latex ascending, descending, and returning upon itself. Besides, at the side of the focus, in the cellular tissue, we remark the cyclosis in distant currents, and the same thing is visible between the cells of the hair. It is observed that the scattered currents, whether in the cellular tissue of the stem, or in the hairs, are neither separate in each cell nor isolated throughout the cellular tissue, but united to the focus of circulation in certain places; so that all the latex circulating in the cellular tissue and the hairs is derived from the focus of the cyclosis. The same things are still more distinctly visible in Campanula rapunculoides.

The great cause which has prevented naturalists from recognising the truth of M. Schultz's discoveries has, doubtless, been the extreme difficulty of observing a vital phenomenon so easily stopped as that of cyclosis; for if vessels are wounded, and it is an operation of great delicacy to avoid injuring them, in preparing their slices for microscopical examination, the motion ceases. Nevertheless, it may found with tolerable facility in the stipules and bark of the Fig, especially of Ficus elastica; in the leaves, and even the valves of the fruit, of Chelidonium; and in the bark of Acer platanoides. In no case, however, is it seen more easily than in the interior sepals of Calystegia sepium, which are thin enough to bear examination, without laceration, when viewed by transmitted light. In the larger vessels (vasa expansa) the latex appears stationary; but in the smaller ramifications it is seen to move rapidly or slowly, by starts or in a steady current, carrying along with it single globules or several together, which are forced along the passage in the vessels, much as pieces of wood might be expected to be carried in water through a narrow and sinuous channel. It looks as if the matter of the latex met with frequent obstructions, which stopped the current for a moment and then gave way, when a rapid flow goes on till it is again interrupted. Professor Morren has also mentioned the young flowers and receptacle of the common Fig, as an extremely easy subject in which to find the motion.

If, however, the fine capillary ramifications of the cinenchyma upon the surface of plants will satisfy the enquirer, the movement of cyclosis may be readily found in almost any lymphatic hair, provided the microscope employed will magnify 350 diameters. Tradescantia virginica is usually employed for this purpose, but in reality any hair will show it, especially if the latex be milky. It is then seen, to use the words of my lamented pupil, Mr. Slack, that each joint of the hair consists of an outer glassy colourless case, enclosing the colouring matter. A nucleus (cytoblast) is situated at the base of the joint, and currents of small particles appear to pass near it or over its surface. Those currents may often be traced through their whole course around the cell, ascending in one part, descending in another, and sometimes two uniting into one. The structure of each joint of the hair appears to be an outer glassy tube, with longitudinal striæ; between this and the colouring matter the moving fluid with its particles exists. The coloured fluid of the hair seems to be enclosed in a membranous sac, which forms an axis round which the moving fluid revolves. The cytoblast must also be external to the sac, as it is in connection with the currents. (*Trans. Soc. Arts*, xlix. p. 41.)

The course which is taken by the sap, after entering a plant, is the next subject of consideration. The opinion of the old botanists was, that it ascended from the roots, between the bark and the wood: but this has been long disproved by modern investigators, and especially by the experiments of Knight. If a trunk is cut through in the spring, at the time the sap is rising, this fluid will be found to exude more or less from all parts of the surface of the section, except the hardest heart-wood, but most copiously from the alburnum. If a branch is cut half through at the same season, it will be found that, while the lower face of the wound bleeds copiously, scarcely any fluid exudes from the upper face; from which, and other facts, it has been fully ascertained that the sap rises through the wood, and chiefly through the alburnum. It is related by Berthellot, that the people of the Canaries tear off the bark of the poisonous Euphorbia canariensis, and suck the limpid sap of the alburnum, which, during its ascent in that part, undergoes but little alteration from its condition when it enters the roots, and does not partake of the deleterious qualities of the descending sap of the bark. Observations of the same nature have also proved that it descends through the bark and liber. But the sap is also diffused laterally through the cellular tissue, and this with great rapidity; as will be apparent upon placing a branch in a coloured infusion, which will ascend and descend in the manner just stated, and will also disperse itself laterally, in all directions, round the principal channels of its upward and downward route. In trees this lateral transmission takes place chiefly through the medullary rays, which keep up a communication between the bark and the heart-wood, and convey to the latter the secretions which the former may have received from the leaves.

With regard to the vessels through which this universal diffusion of the sap takes place, it has already been stated that its upward course is always through the woody tissue, and partially also through the articulated bothrenchyma; and that it passes downwards through the parenchyma, and woody tissue of the bark, and through the vessels of the latex. But there can be no reasonable doubt that it is also dispersed through the whole system, by means of some permeable quality of the membranes of the cellular tissue, invisible to our eyes, even aided by the most powerful glasses. It has also been suggested that the sap finds its way upwards, downwards, and laterally, through the intercellular passages. That such a channel of communicating the sap is employed by nature to a certain extent I do not doubt, especially in those plants in which the intercellular passages are very large; but whether this is a universal law, or has only a partial operation, is unknown, and is not perhaps susceptible of absolute proof.

The accumulation of sap in plants appears to be attended with very beneficial consequences, and to be deserving of the especial attention of gardeners. It is well known how weak and imperfect is the inflorescence of the Turnip tribe forced to flower before their fleshy root is formed; and how vigorous it is after that reservoir of accumulated sap is completed. Knight, in a valuable paper upon this subject, remarks that the fruit of Melons which sets upon the plant when very young uniformly falls off; while, on the contrary, if not allowed to set until the stem is well formed, and much sap accumulated for its support, it swells rapidly, and ripens without experiencing any deficiency of food in the course of its growth. In like manner, if a fruit tree is by any circumstance prevented bearing its crop one year, the sap that would have been expended accumulates, and powerfully contributes to the abundance and perfection of the fruit of the succeeding year.

The cause of the motion of the sap is a subject which has greatly excited curiosity, and given rise to numberless conjectures. It was for a long time believed that there was a sort of circulation of the sap of plants, to and from a common point, analogous to that of the blood of animals; but this was rendered improbable by the well-known fact that a plant is more analogous to a polype than to a simple animal; that it is a congeries of vital systems, acting indeed in concert, but to a certain degree independent of each other, and that consequently it has myriads of seats of life. It was, moreover, experimentally disproved by Hales. This excellent observer, whose *Statics* are an eternal monument of his industry and skill, thought that the motion of the sap, the rapidity of which he had found to be greatly influenced by weather, depended upon the contraction and expansion of the air, which exists in great quantities in the interior of plants. Others have ascribed the motion to capillary attraction. Knight was once of opinion that it depended upon a hygrometrical property of the plates of silver grain (medullary rays), which traverse the stem in all directions. The same physiologist considered that the mechanical agitation of stems and branches by wind was favourable to the motion: he confined the stem of a tree, so that it could vibrate only in one plane; and, at the end of some years, he observed that its section was an ellipse, whose greater axis lay in this plane. Other theorists have called to their aid a supposed irritability of the vessels; but no contraction of the vessels has ever yet been noticed, except under the influence of frost, as shown by Biot. Du Petit Thouars suggests that it arises thus:—In the spring, as soon as vegetation commences, the extremities of the branches and the buds begin to swell: the instant this happens a certain quantity of sap is attracted out of the circumjacent tissue for the supply of those buds: the tissue, which is thus emptied of its sap, is filled instantly by that beneath or about it: this is in its turn replenished by the next; and thus the whole mass of fluid is set in motion, from the extremities of the branches down to the roots. Du Petit Thouars is, therefore, of opinion that the expansion of leaves is not the effect of the motion of the sap, but, on the contrary, is the cause of it; and that the sap begins to move at the extremities of the branches before it stirs at the roots. That this is really the fact, is well known to foresters and all persons accustomed to the felling or examination of timber in the spring; and to gardeners who are occupied with forcing the branches of plants in winter, while their trunks are exposed to the weather. Some good observations upon this were communicated to Loudon's *Gardener's Magazine*, by Mr. Thomson, gardener at Welbeck; who, however, drew a wrong inference from them.

The following observation gives additional weight to the opinion of Du Petit Thouars: —

M. Gaudichaud found, when in Brazil, that, upon cutting through one of the creeping Cissi (C. hydrophora), the sections only slightly discharged fluid when the upper part was merely divided from the under; but that when a truncheon, of whatever length, was separated from the stem, the sap then ran out in great quantity from either end, according to which was held downwards, and that it only dropped out slowly when held in a horizontal position. Upon examining the next day the cut end of the lower part of this stem, it was found dry for 5 or 6 inches below the wound. M. Gaudichaud ascribes the latter circumstance to the pressure of the atmosphere upon the orifices of the tubes; and the absence of any considerable amount of bleeding in the upper half, to the power of suction in the leaves, &c.; while he attributes the ready discharge of fluid from either end of the separated truncheon to atmospheric pressure, which, he supposes, operates upon the vessels of the Cissus, as it would upon inert tubes. (*Ann. Sc.*, n. s., vi. 142.)

Dutrochet has formed a theory of all the motions of fluids in plants depending upon the agency of galvanism. He found that small bladders of animal and vegetable membrane, being filled with a fluid of greater density than water, securely fastened, and then thrown into water, acquired weight; he also remarked, that if the experiment was reversed, by filling them with water and immersing them in a denser fluid, the contrary took place, and that the bladders lost weight. He took a small bladder, and filled it with milk, or gum arabic dissolved in water; to the mouth of this bladder he adapted a tube, and then plunged the bladder in water: in a short time the milk rose in the tube, whence he inferred that water had been attracted through the sides of the bladder. This experiment was also reversed, by filling the bladder with water, and plunging it in milk: the fluid then fell in the tube, whence he inferred that water had been attracted through the coat of the bladder into the milk. From these and other experiments, Dutrochet arrived at the inference, that, if two fluids of unequal density are separated by an animal or vegetable membrane, the denser will attract the less dense through the membrane that divides them: and this property he calls *endosmose*, when the attraction is from the outside to the inside; and *exosmose*, when it operates from the inside to the outside. In pursuing this investigation, he remarked that, if an empty bladder is immersed in water, and the negative pole of a galvanic battery introduced into it, while the positive pole is applied to the water on the outside, a passage of fluid takes place through the membrane, as had previously happened when the bladder contained a fluid denser than water; by reversing the experiment, the reverse was found to take place: from all which Dutrochet deduces the following theory: —That, when two fluids of unequal density are separated by an intervening membrane, the more dense is negatively electrified, and the less dense positively electrified; in consequence of which, two electric currents of unequal power set through the membrane, carrying fluid with them; that which sets from the positive pole, or less dense fluid, to the negative pole, or more dense fluid, being much the more powerful: and that the fluids of plants being more dense than those which surround them, a similar action takes place between them and the water in the soil, by means of which the latter is continually impelled into their system. Philosophers do not seem disposed to admit the legitimacy of Dutrochet's conclusion, that this transmission takes place by means of galvanic agency; but that the phenomenon is correctly described by the ingenious author, and that it is constantly operating in plants, are beyond all dispute. It is by endosmose that vapour is absorbed from the atmosphere, and water from the earth; that sap is attracted into fruits by virtue of their greater density; and, probably, that buds are enabled to empty the tissue that surrounds them, when they begin to grow.

But, although endosmose will be found a ready explanation of many of the phenomena connected with the ordinary movement of fluids, it throws no light upon rotation or cyclosis, which, so far as we at present know, are motions inexplicable upon any principle yet discovered.

CHAPTER XIV.

OF THE DIRECTIONS TAKEN BY THE ORGANS OF PLANTS.

THE substance of all that is known upon this subject has been combined with some excellent observations of his own, by Dutrochet, in a memoir, of which I shall avail myself in the following remarks.

"The general phenomena of nature," says this writer, "which are daily before our eyes, are often those which mankind considers the least attentively. Those who are unaccustomed to reflect upon such subjects can scarely believe that there is any very extraordinary mystery in the ascent of the stems of vegetables, or in the descent of their roots; and yet this is one of the most curious circumstances connected with vegetable life. The downward direction of the roots may appear easy of explanation: it may be said that, like all other bodies, they have a tendency towards the centre of the earth, in consequence of the known laws of gravity (as is the opinion of Knight, in *Phil. Trans.* for 1806); but on what principle, then, is to be explained the upward tendency of the stem, which is in direct opposition to those laws? And here lies the difficulty. Dodart is the first who appears to have paid attention to this circumstance; he pretends to explain the turning backwards of seeds sown in an inverted position by the following hypothesis: — He assumed that the root is composed of parts that contract by humidity; and that the stem, on the contrary, contracts by dryness. For this reason, according to him, it ought to happen that, when a seed is sown in an inverted position, the radicle will turn back towards the earth, which is the seat of humidity; and that the plumula, on the contrary, turns to the sky, or rather atmosphere, a drier medium than the earth. The experiments of Du Hamel are well known, in which he attempted to force a radicle upwards and a plumula downwards, by enclosing them in tubes which prevented the turning back of these parts. It was found that, as the radicle and plumula could not take their natural direction, they became twisted spirally. These experiments, while they prove that the opposite tendencies of the radicle and plumula cannot be altered, still leave us in ignorance of the cause of such tendencies. We are equally ignorant of the cause of the directions of the leaves. Bonnet believed that he could explain that phenomenon upon the hypothesis of Dodart just referred to, with respect to the radicle and plumula. According to him, the lower surface of the leaves is, like the radicle, composed of fibres which contract by humidity; and the upper, like the plumula, of fibres that contract by dryness. As a proof of these assertions, Bonnet manufactured some artificial leaves: the upper surface of which was parchment, which contracts by dryness, and the lower of linen, which contracts by moisture. These leaves were submitted to the action of dryness and humidity; and Bonnet found they were affected much in the same way as true leaves, — so easy is it to find proofs to support a favourite hypothesis."

In consequence of the unsatisfactory nature of these and other theories, more modern physiologists have been satisfied with inscribing the particular directions taken by plants among the *vital phenomena* of vegetation. And this is, perhaps, as much as we are likely to ascertain relating to them, and all similar manifestations of the overruling power of nature. Dutrochet, however, being of opinion that some more direct explanation of such phenomena is to be found, instituted a variety of experiments of a novel kind. "Seeing," he remarks, "that the stem is always directed towards heaven, and the root towards the earth, we cannot but believe that there is some relation between the cause of gravitation and that of the life of vegetables: the constant direction of the stem towards the light leads us also to suppose that this agent performs some important part in determining the directions of the parts of plants. The stem must be placed in the midst of the atmosphere, in order to develope itself; the roots, on the contrary, require to lie within the earth. Hence, it may be inferred that several causes concur to produce the phenomena in question."

Dutrochet filled with earth a box, the bottom of which was perforated with many holes: he placed seed of the Kidney-bean in these holes, and suspended the box in the air, at about eighteen feet from the earth. Here the seeds, being placed in holes pierced through the bottom of the box, received the influence of the atmosphere and light from below; while the humid earth was placed above them. If the cause of the different directions of the radicle and plumule consisted in an affinity of the former for humidity, and of the latter for the atmosphere, the radicle ought to shoot upwards, and the plumule downwards; but this did not take place. The radicles, on the contrary, found their way downwards out of the box into the atmosphere, where they quickly dried up and perished; and the plumules forced their way backwards into the earth. This experiment was afterwards modified, by increasing the quantity of earth above the seeds, and by some other contrivances; but the result was always the same: it was uniformly found, that there was no affinity between the radicle and the seat of moisture sufficient to counteract the natural downward tendency of the roots. It was also inferred, that there existed no more positive affinity between the stems and the atmosphere than between the roots and water.*

There are certain parasitic plants which strike their roots into the stems of other plants, and which always grow at right angles with the stem to which they are fixed. The seed of the Mistletoe will germinate in any direction, either upwards, downwards, or laterally. The first movement made by this plant consists in an extension of its caulicule, which derives its support from the cotyledons, and which terminates at the radicular end in a small green tubercle of a paler colour than the radicle itself. When the seed is fixed upon a branch by its natural glue, this incipient movement is effected at right angles with the branch; the young shoot is then curved backwards, and the radicular extremity descends to the surface of the branch, to which it adheres by expanding into a kind of disk. From this expansion the roots are emitted, and penetrate the interior of the branch whereon the seed of the Mistletoe is fixed: its stem takes the directions above mentioned with reference to the centre of the branch on which it is fixed, and not with reference to the earth; so that, with regard to the latter, it is sometimes ascending, sometimes descending, sometimes horizontal. The same phenomena occur if the germination takes place upon dead wood or inorganic substances: a number of seeds were glued to the surface of a cannon ball; all the radicles were directed towards the centre of the ball. Hence it is obvious that the tendency of the Mistletoe is not towards the surface of its nutrition, but that it obeys the attraction of the body upon which it grows. The Mistletoe, which does not grow on the earth, obeys the attraction of any other body; while those plants which naturally grow in the earth obey no other attraction than that of the earth. Parasitical Fungi, those which constitute mouldiness, aquatics which originate on stones, — all grow perpendicular to the body that produces them, and will therefore be placed in all kinds of positions with respect to the earth.

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* Professor Schultz, however, succeeded in overcoming the tendency of the roots downwards and stems upwards. He planted seeds of Cabbages, Mustard, and Kidneybeans in moss, and so arranged them that the only light they could receive was from a mirror, which threw the solar rays upon them from below upwards; they sent their roots upwards, and their stems downwards. It would, therefore, appear that light is the great cause of the direction taken by the stem.

The tendency downwards of the roots, and upwards of the stem, is chiefly observable in the ascending and descending caudex; that is to say, in the axis of the vegetable considered as a whole. The lateral emissions of this axis always deviate from its direction in a greater or less degree: we know that the roots produced by the taproot, and the branches which proceed from the side of the principal stem, scarcely ever take a direction absolutely vertical. This is probably due to several causes, one of which is undoubtedly the general tendency of all the parts of plants to take a direction perpendicular to the plane of the body on which they grow. The branches of trees are, to those which produce them, what the

Mistletoe is to the branch on which it vegetates: but, as there is a double attraction operating upon all branches,—that is to say, an attraction towards the stem and an attraction upwards, in consequence of the general law to which they all submit,—it results that a middle direction is taken, and, instead of a branch continuing to grow at right angles with some other, it soon abandons that direction, and points its extremity towards the sky.*

It has been hitherto seen, that the roots of vegetables are positively attracted by the body on which they grow; it appears, however, from the following experiment, that this attraction is influenced essentially by the mass of the body. Thus, if a seed of Mistletoe is made to vegetate on a thread, the radicle turns itself in all sorts of ways, and exhibits no signs of attraction to the thread. Dutrochet made a seed of Mistletoe germinate on a thread; he then glued it upon one of the points of a fine needle, fixed like that of a compass, balancing it by a bit of wax at the other end of the needle; he next placed a piece of wood at about half a line's distance from the radicle; and then covered the whole apparatus with a glass, placed under such conditions that it was impossible that any cause could move the needle. In five days the embryo began to bend, and direct its radicle towards the bit of wood, without the needle's changing its position, although it was extremely movable upon its centre: in two days more the radicle was directed perpendicularly to the bit of wood, with which it had come in contact, and still the needle had not stirred. This proves, says Dutrochet, that the direction of the radicle of the Mistletoe towards a neighbouring body is not the immediate result of any attraction on the part of such a body; but that it is the result of a spontaneous movement of the embryo, in consequence of the attracting influence exerted upon its radicle, which is thus the mediate or occasional cause of the phenomenon. It is obvious, indeed, that the inflexion of the stem of the embryo of the Mistletoe could not be due to the immediate attraction on the part of the bit of wood; for an exterior power sufficient to produce this inflexion would much more readily have produced a change in the direction of the needle, to one of whose points the seed was fixed: there can, therefore, be no doubt that the movement was *spontaneous;* that is to say, that it was produced by an internal vital cause, put in action by the influence of an exterior agent. This spontaneous direction of the radicle of the Mistletoe, under the influence of attraction, proves incontestably that attraction only influenced its nervous powers, and not its ponderable matter: and the same is undoubtedly the case with terrestrial plants. The unknown power of attraction is only the accidental cause of the ascent of the stem, and of the descent of the roots, and not the immediate cause: in this case, attraction only operates as an agent for exciting nervous action. Other evidence exists to confirm this important conclusion, that the visible movements of vegetation are all *spontaneous;* being brought into action by the influence of an external agent, but not movements originating with that agent.

Light is another cause of no less power than that just described. It is well known that a plant, placed in a room from which the light is excluded except at a single aperture, directs its stem and leaves towards that aperture, and no longer takes a perpendicular position. This is accounted for by De Candolle as follows: — Let any one expose a green branch in such a manner that light strikes it only on one side; the tissue of that side will fix most carbon, will become harder, and will lengthen less; while the opposite will fix less carbon, be less hard, and will lengthen more; the consequence of which will be, that the illuminated side will contract, and pull the branch towards the light. This, if rightly considered, will of itself explain the uniform tendency of the green parts of plants to turn towards the light; and if it will not account for such phenomena as that of the Sunflower turning its flowers constantly to the sun, and following him in his course, as we find repeated by author after author, that circumstance is ascribable, not to any defect in the explanations that have just been given, but *to the alleged phenomenon having no existence in nature.* The same tendency of the stems towards the light takes place in the open air. As light is diffused nearly equally around all bodies exposed to it, carbonic acid will be decomposed equally on all sides, and the various parts will naturally assume a direction towards the heavens; so that light thus becomes an aid to gravitation. It might even be believed that light alone was a sufficient cause of the perpendicular position of the stems of vegetables, if experience did not prove the contrary. Dutrochet laid horizontally on the ground, in a dry and dark place, the stems of Allium Cepa and Allium Porrum, taken up with their bulbs. These plants, although taken out of the ground, continued to live for a long time; their stems became curved, and their upper end took a direction towards the heavens. This happened in about ten days; but, being repeated in the open air, three days were sufficient to produce the direction. In the first experiment, light being wholly excluded, gravitation only could have operated in giving the stem a perpendicular direction; that power being the only one which is known to act in a direction perpendicular to the horizon. Modifications of this experiment were instituted, to be certain that humidity had no effect, and the same result was obtained. In the prosecution of these investigations, it also appeared that it was not merely the summit of the stem which had a tendency to a perpendicular direction, but that all the movable parts of the plant possessed a similar disposition, provided they were coloured.

Stems are sometimes directed towards the earth, in which they attempt to bury themselves like roots; a phenomenon worthy of the greatest attention, not only on its own account, but for the sake of the circumstances connected with it. Many vegetables, besides their above-ground stems, have also subterranean stems: these creep horizontally in the interior of the earth, without manifesting any tendency towards the sky; they are white, like roots, of which they assume the course and the station. Sometimes, however, they are pink, as in Sparganium erectum; in such cases it is the epidermis that is coloured, and not the subjacent parenchyma: but, whenever the point of their stems approaches the surface of the soil, it becomes green, and, from that moment, they acquire an upward tendency. Is it hence to be inferred, that there is some secret connection between the colours of the parts of vegetables and the directions they assume?

" Generally," Dutrochet proceeds to remark, " stems are directed towards the light, which is in accordance with their usually green colour; while the roots have usually a tendency to avoid the light, which coincides with their want of colour. The colour of the roots is, in fact, nothing but that of the vegetable tissue; and can by no means be compared to that of the petals of some plants, which arises from the presence of a white colouring matter. Light, which is the principal, but not sole, cause of the colour of stems and their organs, has no power of infusing colour into the roots, as may be easily seen by roots growing in glasses of water; in spite of the influence of the light they constantly remain colourless; and this does not depend upon immersion in water, because leaves developed in that medium are nevertheless green. Although roots have, in general, no tendency towards the light, yet such a disposition does become manifest, provided the terminal shoot of a root becomes slightly green, as occasionally happens. Having induced some seeds of Mirabilis Jalapa to germinate in damp moss, I remarked that the young roots, when about as long as the finger, were terminated by a shoot of a slightly green colour. Wishing to know whether these roots would turn towards the light, I placed them in a glass vessel filled with water, having a wooden cover pierced with holes to receive the roots and fix the seeds. I enveloped the vessel in black cloth, leaving only a narrow vertical slit, through which light could enter the interior. This slit was exposed to the rays of the sun; and, a few hours after, I found that all my roots had hooked back their points towards the slit through which light was introduced. The same experiment was tried with colourless roots; but no alteration in their direction was produced. From this it appears evident, that colour is one of the conditions that determine the directions of vegetables and their parts towards the light, and consequently towards the sky. This is so true, that colourless stems are known to assume the directions of roots. In the Sagittaria sagittifolia this is particularly obvious. Shoots are produced from the axillæ of all the radical leaves which grow at the bottom of the water. These shoots have their points directed towards the sky, like those of all vegetables. The young stems which are produced by these shoots are entirely colourless, like roots; and, instead of taking a direction towards the sky, as coloured stems would do, they lead downwards, pointing towards the centre of the earth. In order to take this position, the young shoot forces its way through the substance of the petiole which covers it; thus overcoming a mechanical obstacle, in its tendency towards the earth. This subterranean stem next takes a horizontal course, and does not assume any tendency towards the sky until the points become green."

Dutrochet has also remarked a similar phenomenon in roots. It is well known that exposed stems of many plants produce roots: when green, they turn upwards, as in Pothos and Cactus phyllanthus; when colourless, they point downwards. Hence it is to be inferred, that stems do not descend merely because they are stems, but because their parenchyma is coloured; and that roots descend, not in their quality of roots, but because their parenchyma is colourless. It seems, however, that although this law is uniform in its operation in all terrestrial plants, yet that a deviation, or apparent deviation, from it exists in the parasitic Mistletoe. The radicle of this plant, which is of a paler green than the other parts, instead of turning towards the light, avoids it with so much pertinacity that it is impossible to induce it to take such a direction; so that it seems to be repelled by light. Dutrochet does not seem to be able to satisfy himself of the reason of this exception: but it appears to be by no means difficult to account for. We have seen that, in the direction of its radicle, nature has enabled it to fulfil its functions as a parasitic plant, by the attraction of the body on which it is placed, rather than by the much more powerful attraction of the earth. In order to insure this particular tendency, without possessing which the existence of the Mistletoe would be put in hazard, its root has received, from the same all-powerful Hand, a disposition so much greater than other plants to avoid light, and to bury itself in the obscurity of the interior of a tree, as to be sufficient to overcome the influence of its green colouring matter.

The next direction of the parts of plants, which may be called *special*, is that of the upper surface of the leaves towards the sky, and of the lower towards the earth. This disposition is so powerful, that, if the usual direction of a leaf be inverted, the petiole will twist so as to enable it to recover itself. This phenomenon has been noticed by Bonnet, whose explanation has been already given, but which is obviously inadmissible. There is always a natural difference between the two faces of the leaf: the upper is always the more deeply coloured; a difference which will be found constant in all cases. The face with the deeper colour turns towards the sky or light, and that with the weaker colour towards the earth or obscurity; and this is so constant a law, that it will be found that if the surface of the leaf which is naturally inferior is more deeply coloured than the superior, the petiole will be twisted round by the greater affinity of the lower surface for the light, which will thus become uppermost, the leaf presenting the appearance of being inverted. This may be seen in many grasses, but best in Zea Mays, Triticum repens, and Agrostis rubra. Hence it is to be concluded, that the upper surface of the leaf is not turned towards the heavens merely in consequence of its quality of being the upper surface, but because it is generally the most deeply coloured.

The same law influences the directions of the petals, in which the upper surface, — that which is turned towards the heavens, — is always the most highly coloured: this, indeed, is sometimes not very apparent, but is nevertheless constant. Even in white petals, — such, for example, as those of Lilium album, — the upper face will be found of a dense but brilliant white, while the lower is of a much paler hue. The white colour of the petals, Dutrochet proceeds to remark, like all the other colours of plants, is due to a particular kind of colouring matter deposited in the parenchyma lying below the epidermis. Thus the whiteness of the flowers of plants is not dependent upon the absence of colour, as in roots and etiolated stems: in the former a white colouring matter exists; in the latter the whiteness is caused by absence of colour. Some apparent exceptions to this law, — such as the outside of many monopetalous flowers being paler than the inside, as in Digitalis purpurea, Fritillaria latifolia, and others, — Dutrochet thinks may be explained thus: — These cases, no doubt, are due to the tendency of the less coloured part to avoid the light, which is manifested by bearing down the flower so as to approach the seat of obscurity as nearly as possible: all such flowers being always nodding. This tendency is aided by the weakness of the peduncle, which seems to have been specially provided for enabling such flowers to retire from the light. In papilionaceous plants, the inside of the vexillum, which is most deeply coloured, always turns itself towards the light; and the alæ twist themselves half round, to effect the same object. The ovaries often take a different direction after the fall of the corolla from what they had before. Thus, during flowering, the ovary of Digitalis purpurea is nodding like the flower, the direction of which it is compelled to follow: immediately after the fall of the corolla, it turns upwards towards the light, to which it is attracted by its green colour. A contrary phenomenon is presented by the ovary of Convolvulus arvensis. The flower is turned towards the sky: as soon as it has fallen, the ovary takes a direction towards the earth, bending down the peduncle. This cannot be due to the weight of the ovary, which is much lighter than its peduncle, but must depend upon its disposition to avoid the light, on account of its pallid hue, which is nearly the same as that of the root. In Calystegia sepium, on the contrary, in which the ovary is equally pale, its erect position is maintained, and the influence of *decoloration* counteracted by the greater affinity to the light of two large green bracts in which it is enveloped.

From the following and some other experiments, Dutrochet infers that the direction of leaves to the light is not mechanically caused by the operation of an external agent, but is due to a spontaneous motion, put in action by the influence of external agency. He took a leaf and cut off its petiole, the place of which was supplied by a hair, hooked by one end upon the leaf, and having a piece of lead attached to its opposite extremity. They were plunged in a vessel of water: the weight of the lead carried the leaf to the bottom of the water, where it stood erect in consequence of its lightness inducing it to attempt to ascend. Being exposed in a window, so that the under surface was turned to the light, no alteration took place in its position. Now, as, from Bonnet's experiments, it is certain that leaves immersed in water act exactly as if surrounded with air, it is to be inferred that the external influence of the light is of no effect, unless aided by a spontaneous power within the vegetable, which was destroyed by the removal of the petiole. Leaves immersed in water under similar circumstances, with their petioles and stem uninjured, turned towards the light as they would have done in the open air.

I am unwilling to give more space to this subject, which belongs less to practical physiology than to speculative philosophy. The reader who wishes to study it will find abundant illustrations, explanations, and speculations in Dutrochet's *Mémoires pour servir à l'Histoire Anatomique et Physiologique des Végétaux :* Paris, 1837.

CHAPTER XV.

OF IRRITABILITY.

THE vitality of plants seems to depend upon the existence of an irritability, which, although far inferior to that of animals, is, nevertheless, of an analogous character.

This has been proved by a series of interesting experiments, by Marcet, of Geneva, upon the exact nature of the action of mineral and vegetable poisons. The subject of his observations was the common Kidneybean ; and, in each experiment, a contrast was formed between the plant operated upon and another watered with spring water. A vessel containing two or three Bean plants, each with five or six leaves, was watered with two ounces of water, containing twelve grains of oxide of arsenic in solution. At the end of from twenty-four to thirty-six hours the plants had faded, the leaves drooped, and had even begun to turn yellow. Attempts were afterwards made to recover the plants, but without success. A branch of a Rose tree was placed in a solution of arsenic; and in twenty-four hours ten grains of water and 0·12 of a grain of arsenic had been absorbed. The branch exhibited all the symptoms of unnatural decay. In six weeks a Lilac tree was killed, in consequence of fifteen or twenty grains of moistened oxide of arsenic having been introduced into a slit in one of the branches. Mercury, under the form of corrosive sublimate, was found to produce effects similar to those of arsenic; but no effect was produced upon a Cherry tree, by boring a hole in its stem, and introducing a few globules of liquid mercury. Tin, copper, lead, muriate of barytes, a solution of sulphuric acid, and a solution of potash, were found to be all equally destructive of vegetable life; but it was ascertained, by means of sulphate of magnesia, that those mineral substances which are innocuous to animals are harmless to vegetables also. In the experiments with vegetable poisons, the Bean plants were carefully taken from the earth, and their roots immersed in the solutions used. It had been previously ascertained, that plants so transplanted and placed in water, under ordinary circumstances, would remain in excellent health for six or eight days, and continue to vegetate as if in the earth. A plant was put into a solution of nux vomica at nine in the morning: at ten o'clock the plant seemed unhealthy; at one the petioles were all bent in the middle; and in the evening the plant was dead. Ten grains of an extract of cocculus suberosus, dissolved in two ounces of water, destroyed a Bean plant in twenty-four hours; prussic acid produced death in twelve hours, laurel water in six or seven hours, a solution of belladonna in four days, alcohol in twelve hours.

From the whole of his experiments, M. Marcet concludes, — 1st, That metallic poisons act upon vegetables nearly as they do upon animals: they appear to be absorbed and carried into different parts of a plant, altering and destroying the vessels by corrosive powers. 2dly, That vegetable poisons, especially those which have been proved to destroy animals by their action upon the nervous system, also cause the death of plants: whence he infers that there exists in the latter a system of organs which is affected by poisons, nearly as the nervous system of animals.

These facts have been confirmed by other experiments of Macaire, which will be mentioned presently.

Irritability, in the common acceptation of the term in botany, means those extreme cases of excitability in which an organ exhibits movements altogether different from those we commonly meet with in plants. Of this kind of irritability there are three distinct classes; namely, those which depend upon atmospheric phenomena, spontaneous motions, and such as are caused by the touch of other bodies.

Among the cases of irritability excited by particular states of the atmosphere, the singular phenomenon called by Linnæus the sleep of plants is the most remarkable. In plants with compound leaves, the leaflets fold together, while the petiole is recurved, at the approach of night; and the leaflets again expand and raise themselves at the return of day.

In others the leaves converge over the flowers, as if to shelter those most delicate organs from the chill air of night. The flowers of the Crocus and similar plants expand beneath the bright beams of the sun, but close as soon as they are withdrawn. The Œnotheras unfold their blossoms to the dews of evening, and wither away at the approach of day. Some Silenes roll up their petals in the day, and expand them at night. The florets of numerous Compositæ, and the petals of the genus Mesembryanthemum, are erect in the absence of sun, but become reflexed when acted upon by the sun's beams; and many other such phenomena are familiar to every observer of nature. It is probable, indeed, that a different effect is produced upon all plants by day and night, although it is less visible in some than in others; thus plants of Corn, in which there is little indication of sleep when grown singly, exhibit that phenomenon very distinctly when observed in masses; their leaves become flaccid, and their ears droop at night. These effects have been generally attributed to the action of light; and it is probable that that agent contributes very powerfully to produce them; for a flower removed from the shade will often expand beneath a lamp, just as it will beneath the sun itself. De Candolle found that he could induce plants to acknowledge an artificial day and night, by alternate exposure to the light of candles. There must, however, be some cause beyond light, of the nature of which no opinion has yet been formed; many flowers will close in the afternoon while the light of the sun is still playing upon them, and the petals of others will fold up under a bright illumination.

Spontaneous movements are far more uncommon than those which have just been described. In Megaclinium falcatum, the labellum, which is connected very slightly with the columna, is almost continually in motion; in a species of Pterostylis, shown me by Dr. Brown, I observed a kind of convulsive action of the labellum; the filaments of Oscillatorias are continually writhing like worms in pain; several Confervas exhibit spontaneous movements in their spores: but the most singular case of the kind is that of Hedysarum gyrans. "This plant has ternate leaves: the terminal leaflet, which is larger than those at the side, does not move, except to sleep; but the lateral ones, especially in warm weather, are in continual motion, both day and night, even when the terminal leaflet is asleep. External stimuli produce no effect; the motions are very irregular; the leaflets rise or fall more or less quickly, and retain their position for uncertain periods. Cold water poured upon it stops the motion, but it is immediately renewed by warm vapour.

To this class of irritability ought, perhaps, to be referred the curious phenomenon well known to exist in the fruit of Momordica Elaterium, the Spirting Cucumber. In this plant the peduncle, at a certain period, when the fruit has attained its perfect maturity, is expelled, along with the seeds and the mucus that surrounds them, with very considerable violence. Here, however, endosmose appears to offer a satisfactory explanation. According to Dutrochet, the fluid of the placentary matter in this fruit gradually acquires a greater density than that which surrounds it, and begins to empty the tissue of the pericarpium: as the fruit increases in size the same operation continues to take place; the pulpy matter in the centre is constantly augmenting in volume at the expense of the pericarpium; but, so long as growth goes on, the addition of new tissue, or the distention of old, corresponds with the increase of volume of the centre. At last growth ceases, but endosmose proceeds; and then the tissue that lines the walls of the central cell is pressed upon forcibly by the pulp that it encloses, until this pressure becomes so violent that rupture must take place somewhere. The peduncle, being articulated with the fruit, at length gives way, and is expelled with violence; at the same time the cellules of tissue lining the cavity all simultaneously recover their form, the pressure upon them being removed, and instantly contract the space occupied by the mucous pulp; the consequence of which is that it also is forced outwards at the same time as the peduncle. It has been found by measurement, that the diameter of the central cavity is less after the bursting of the fruit than before.

Movements produced by touch, or by external violence, are very frequent. The Sensitive Plant (Mimosa pudica), which will rapidly fold up its leaves as if in a state of sleep, is, perhaps, the most familiar instance: but many others also exist. If any one of six bristles planted perpendicularly upon the leaf of Dionæa muscipula is irritated, the sides of the leaf collapse, so as to cross the ciliæ of their margin, like the teeth of a steel-trap for catching animals. Roth is recorded to have seen something of the same kind in Drosera rotundifolia. If the bottom of the stamens of the common berberry is touched on the inside with the point of a needle, they spring up against the pistillum. The valves of Impatiens noli-tangere, when the fruit is ripe, separate and spring back with great elasticity when touched. In this case the phenomenon is apparently capable of explanation upon a similar principle to the Momordica Elaterium. In the fruit of Impatiens, the tissue of the valves consists of cellules that gradually diminish in size from the outside to the inside; and the fluids of the external cellules are the densest. The latter gradually empty the inner cellules and distend themselves; so that the external tissue is disposed to expand, and the internal to contract, whenever any thing occurs to destroy the force that keeps them straight. This at last happens by the disarticulation of the valves, the peduncle, and the axis; and then each valve rapidly rolls inwards with a sudden spontaneous movement. Dutrochet proved that it was possible to invert this phenomenon by producing exosmose: for that purpose he threw fresh valves of Impatiens into sugar and water, which gradually emptied the external tissue, and, after rendering the valves straight, at length curved them backwards.

The column of the genus Stylidium, which in its quiescent position is bent over one side of the corolla, if slightly irritated, instantly springs with a jerk over to the opposite side of the flower. In Kalmia the anthers are retained in little niches of the corolla; and, as soon as they are by any cause extricated, the filaments which had been curved back recover themselves with a spring. In certain orchidaceous plants, of the tribe called Vandeæ, the caudicula to which the pollen masses are attached will often, upon the removal of the anther, disengage itself with a sudden jerk.

For numerous observations upon other cases of vegetable irritability, see Dutrochet's *Mémoires* previously quoted, in which there is much ingenious speculation upon the immediate causes of this singular property.

That a peculiar kind of irritability does exist in plants, not very different from what we remark in animals, has been shown in part by the experiments of Marcet already quoted, and still more by those of Macaire.

The former observer proved that narcotic and irritating poisons produce an effect upon vegetables altogether analogous to that which they produce upon animals. The very valuable experiments with gases by Turner and Christison, mentioned formerly, lead to the same conclusion. These gentlemen remark that "the phenomena, when compared with what was observed in the instances of sulphurous and hydrochloric acid, would appear to establish, in relation to vegetable life, a distinction among the poisonous gases, nearly equivalent to the difference existing between the effect of the irritant and the narcotic poisons on animals. The gases which rank as irritants in relation to animals seem to act locally on vegetables, destroying first the parts least plentifully supplied with moisture. The narcotic gases, — including under that term those that act on the nervous system of animals, —destroy vegetable life by attacking it throughout the whole plant at once. The former, probably, act by abstracting the moisture of the leaves; the latter, by some unknown influence on their vitality. The former seem to have upon vegetables none of that sympathetic influence upon general life, which in animals follows so remarkably injuries inflicted by local irritants."

A similar result was arrived at by Macaire, whose experiments are recorded in the *Bibliothèque Universelle*, xxxi. 244., and which appear of sufficient importance to be detailed at length.

The first plant used was the Berberis vulgaris. The six stamina of the flowers of this plant have the property of rapidly approaching the pistil, when touched by the point of an instrument. The motion occurs at the base of the stamens. When cold, the motion is sometimes retarded. When put into water or solution of gum, the flowers may be preserved many days, possessing their irritability. The petals and stamens close at night to open again in the morning. Putting the stem of this plant into dilute prussic acid for four hours, occasioned the loss of the contractile property by irritation; the articulation became flexible, and might be inclined in any direction by the instrument. The leaves had scarcely begun to fade. On placing the expanded flowers on the prussic acid, the same effect took place, but much more rapidly.

The experiment being repeated with an aqueous solution of opium, a similar effect was produced in nine hours.

Dilute solutions of oxide of arsenic and arseniate of potash were used: the stamens lost the power of approaching the pistil; but they were stiff, hard, withdrawn backwards, and could not have their direction altered without fracture. It seemed like an irritation, or a vegetable inflammation.

Solution of corrosive sublimate more slowly produced the same effects.

Sensitive Plant (Mimosa pudica). — Experiments were now made with this vegetable. When a leaf of this plant is cut, and allowed to fall on pure water, the leaflets generally contract rapidly; but after a few moments expand, and are then susceptible of contraction by the touch of any other body. They may thus be preserved in a sensible state two or three days. If the section be made with a very sharp instrument, and without concussion, the leaves may be separated without any contraction. The branches of this plant may be preserved for several days in fresh water. Gum-water also effects the same purpose.

When a cut leaf of this plant falls upon a solution of corrosive sublimate, the leaf rapidly contracts, and the leaflets curl up in an unusual manner, and do not again expand. When put into pure water, the sensibility does not return, but the whole remains stiff and immovable. A little solution of corrosive sublimate, being put into a portion of pure water containing an expanded branch of the plant, gradually caused curling up of the leaves, which then closed and fell. If the solution be very weak, the leaves open on the morrow, and are still sensible, but ultimately contract, twist, and remain stiff till they die. Solutions of arsenic and arseniate of potash produce the same effects.

A leaf of the Sensitive Plant was in a cold diluted solution of opium: in a few moments it opened out as in water, and, after half an hour, gave the usual signs of contractibility. In six hours it was expanded, and had a natural appearance, but could not be excited to move. The leaflets were flexible at the articulations, and offered a singular contrast to the state of irritation produced by corrosive sublimate. Pure water did not recover the plant. A large branch, similarly situated, expanded its leaves; but in half an hour had lost much of its sensibility: the leaflets, though alive, seemed asleep, and required much stimulating to cause contraction. In one hour the contractions ceased: in two hours the branch was dead.

A leaf placed in prussic acid (Scheele's strength) contracted, then slightly dilated, but was quite insensible, and the articulations were flexible: water did not recover it. If the acid be very weak, the leaflets dilate and appear to live, but are insensible. A drop of the acid placed on two leaflets of a healthy plant gradually causes contraction of the other leaflets, pair by pair. Solutions of opium and corrosive poisons have no effect when applied this way. After some time they dilate, but are insensible to external irritation: the sensibility returns in about half an hour; but the leaflets appear as if benumbed.

The plant exposed to the vapour of prussic acid is affected in the same way. Ammonia appears to favour the recovery of the plant.

A cup containing dilute prussic acid was so placed that one or two leaves, or sometimes a branch, of a healthy plant could be plunged into the liquid, or left to repose on its surface. The leaflets remained fresh and extended, but were almost immediately insensible. Being left in this state for two hours, they were expanded; and no irritation could cause their contraction, though otherwise there was no appearance of an unnatural state. At five o'clock in the evening the leaves were left to themselves. At nine o'clock they were open and insensible. At midnight they were still open, whilst all the rest of the plant, and the neighbouring plants, were depressed, contracted, and in the state of sleep. On the morrow they resumed a little sensibility, but seemed benumbed.

In the same manner Macaire has interfered with other plants as to the state of sleep, and observes that prussic acid thoroughly deranges the botanical indications of time of Linnæus.

CHAPTER XVI.

OF COLOUR.

There is no subject connected with the vital phenomena of either plants or animals more unintelligible than the distribution of colour over their surface; a distribution which is evidently caused by some fixed rule, because we often see it perpetuated, with little or no variation, from generation to generation, but concerning the primary cause of which we are as much in the dark as ever.

In De Candolle's *Physiologie Végétale* there is a good account of what was known or conjectured upon this subject in the year 1831, particularly of the views of Schübler and Funk; since that period the subject has been investigated by several persons, especially by Mohl, whose views are incorporated in the following sketch.

Every one must have been struck with the singular, and often complicated, manner in which the various and varying colours of organic matter are arranged. We see in birds the plumage marked with contrasts of the most dissimilar colours, reproduced with an exactness which is wonderful; we find the breeders of curious races of animals able to preserve peculiar kinds of marking, and even to improve them, with admirable precision; we also know that in plants, without any visible constitutional change, without accident, and without any known predisposing cause, a yellow flower will become pink, and a pink one yellow; and we see that, if the portion of a stem thus altered be increased by the division of itself, the change is fixed and may be multiplied for ever. A dingy brownish purple tulip will suddenly, and without warning, burst forth in radiant beauty, its dull colour dispersed, a pure and spotless white taking its place in part, and the brightest and deepest streaks of crimson adding richness to its purity. If we look minutely to these circumstances, we shall find that in plants each particular cell of the parenchyma has its own colour, that there is no intermixture of tints, but that whatever the hues may be, each has its own cluster of cells to represent it: and even in the midst of a large mass of uniform colouring, a few cells, or even a single one, will secrete a colouring matter which forms the strongest contrast with what surrounds it; as in the blood-red orange, and similar cases.

" We are so accustomed," says De Candolle, " to see plants decorated with the most brilliant colours, or invested with the green hue which characterises every scene, that we cannot without difficulty accustom ourselves to the idea that such colours do not exist in a primitive state, but are communicated to vegetation by its own act, as it were; and yet this is the exact truth. The tissue of plants is for the most part colourless, of a silvery white or of an exceedingly pale yellow; the matter originally contained in the tissue is, with a few exceptions, of the same hue; but all is changed when plants are once exposed to solar light.

" We are accustomed to say that green plants become white in total darkness, because the phenomenon, inaccurately observed, is usually presented to us under that form: but the truth is, that although the parts of plants which originally are white or black become more or less coloured when exposed to the action of light, yet organs once coloured do not in reality lose their colour when kept in darkness; if they sometimes seem to do so it is owing to this, that if half-developed leaves are placed in the dark they grow larger, and the green matter which coloured them, being diluted by water and spread over a greater space, appears to be paler without being itself less coloured. That the action of solar light is, in reality, the grand cause of colour in plants is proved by leaves half covered from light and half exposed, of which the latter become green and the former remain colourless; all gradations of intensity being produced in proportion to the intensity of light to which the parts are exposed.

" There are plants which, in the parts destined to become green, have spaces that preserve their original whiteness: such plants we call variegated, and find through almost all the divisions of the vegetable kingdom. In Exogens the blotches are for the most part irregular; in Endogens they are usually arranged in bands that follow the course of the principal veins. In these places it is clear that *chromule*, or colouring matter, is either not found at all or in very small quantity; but the cause of the deficiency is entirely unknown. It is, however, interesting to remark, that variegations of this kind are best preserved in sterile, and are soonest lost in fertile, soil, as if they were in reality an unhealthy state of a plant; a supposition, however, which there are no sufficient grounds otherwise for entertaining.

" We have already seen that all parts which either are green or susceptible of becoming so, decompose the carbonic acid of the sap or of the atmosphere, when they are exposed to solar light; that they part with the oxygen, and fix the carbon in their own tissue. Hence it was natural to conclude that this operation is connected with the formation of a green colour. In fact, when it takes place greenness does ensue; when it does not take place, the organ that developes in darkness preserves the primitive white colour of the tissue; and when it has taken effect incompletely, the results are intermediate between the two preceding cases.

" The deposition of carbon thus induced does not act upon the vegetable membrane; which always retains its original pearly lustre. But it forms a peculiar matter called *chlorophyll* or green *chromule*; the abundance or scantiness of which is what causes the different tints of leafy surfaces. The action of the membrane produces some effect, no doubt, either by reason of its own pallid hue, or its transparency or density; or of the hairs with which it is often covered; or of the air which it contains; or, finally, of the waxy matter by which they are protected. But how does it happen that carbon, which is black, is capable of producing a green appearance in vegetation? The old physiologists supposed that it is in reality an intense blue, and not a black; and that, shining through the yellow sides of the cells, the combination of the two colours produced green. This notion, however, is disproved by the most casual inspection, for the colouring matter may be separated from the tissue with the greatest facility, and it still preserves its colour; and, besides, the yellow of tissue, if any, is so excessively feeble, as to be wholly insufficient to overcome the blueness of the carbon, if *it were blue*. The fact is, that the cause of carbon in the system of vegetation being green, belongs to that numerous class of facts of which no explanation can be given, in the existing state of human knowledge.

"Although we are justified by the mass of evidence, in asserting that the green colour of plants is owing to the fixation of carbon in their tissue, in consequence of the power that light possesses of decomposing their carbonic acid, yet there are some exceptions that deserve attention. Humboldt found Poa annua and compressa, Plantago lanceolata, Trifolium arvense, Wallflower, and the Rhizomorpha verticillata, green in the subterranean galleries of the mines of Freyburg, although born in total darkness, but in atmosphere highly charged either with hydrogen or nitrogen. Ferns and Mosses, again, will be green where other plants are blanched; and Humboldt found near the Canaries a Fucus which was bright grass-green, although it had grown at the depth of from 25 to 32 fathoms (190 feet). Now, as light, according to the experiments of Bouguer, after traversing 180 feet, is weakened in the proportion of 1 to 1477·8, this Fucus must have been illuminated where growing by a power 203 times less than that of a candle at a foot's distance. Are we to suppose that this feeble degree of illumination was sufficient to decompose the carbonic acid of such a plant, or was not the decomposition rather owing to the operation of some unknown cause?

"Leaves, which, as we very well know, are usually green, may assume different colours in special cases. It is common to see in the autumn this green change to yellow, as in the Lombardy Poplar, &c.; or to red, as in the Berberry, the Sumach, the Virginian Creeper, and many kinds of Oaks. It is remarked that red colours are most common in leaves which contain some kind of acid, as the Vine, the Pear, the Viburnum, the Sorrel, &c. The red colouring matter obtained from leaves forms infusions which, like those from flowers, become more intense when acted upon by acids. Yellow leaves act in this manner like yellow flowers. It is supposed by some, that, while red is owing to the developement of acid, other colours may be ascribed to the presence of an alkali. This is, however, far from proved.

" The same colours which stain leaves in the autumn may also be produced by certain accidents. Thus the puncture of an insect, the attacks of parasitical fungi, or injury from early frosts, produce partially or entirely yellow or red colours; and, what is remarkable, the colours thus accidentally assumed are the same as the plant would have taken of itself in the autumn: thus accidents turn the leaves of the Poplar and the Lilac yellow, of the Sumach or the Pear tree red, as they become in the autumn.

" Certain leaves offer naturally, on one or both their surfaces, marks coloured in a particular manner, from the moment when they first unfold. Tradescantia discolor, and several Begonias, have their under surface red; certain Arums are irregularly blotched with red; there are species of Amaranth which, in an apparently healthy and natural state, have leaves banded with both yellow and red. It is worthy of note, that in regular and natural colourations red is very common, and yellow comparatively rare, although one would have thought that the latter, caused, as it seems to be, by a slighter kind of change than red, would have been the most common. Blue seems altogether excluded from changes of the leaves, except in the case of certain Eryngoes.

" In many plants, the leaves which grow in the vicinity of flowers are accustomed to offer various tints, which are almost uniformly in unison with the colours of the flowers they accompany; such floral leaves or bracts are yellow in many Euphorbias, scarlet in Sages, violet in Clary, and blue in particular states of the Hydrangea.

" Why then should it be different with petals and the petal-like parts of a flower? These organs are in truth nothing but modified leaves; they are capable in particular cases, such as Hesperis matronalis, of transforming themselves into genuine leaves, green, and capable of exhaling oxygen."

With regard to the exact relation that colours really bear to one another, and to the causes that are supposed to influence them, a memoir upon the colours of flowers, published at Tubingen, in 1825, by Messrs. Schübler and Funk, is deserving of attention. From their account it appears that flowers may be divided into two great series: those having yellow for their type, and which are capable of passing into red or white, but never into blue; and those of which blue is the type, which can pass into red or white, but never yellow. The first of these series is called by these observers oxidised, and the second disoxidised; and they consider greenness as a state of equilibrium between the two series. De Candolle calls the first series *xanthic*, and the last *cyanic*. Upon this principle they admit the following scale, leaving white out of consideration: —

Red	Xanthic series	Red	Cyanic series.
Orange-red		Violet-red	
Orange		Violet	
Orange-yellow		Violet-blue	
Yellow		Blue	
Yellow-green		Greenish-blue	

Green, Colour of leaves.

Which may be otherwise expressed thus: —

Green.

Cyanic series.	Greenish-blue	Yellow-green	Xanthic series.
	Blue	Yellow	
	Violet-blue	Orange-yellow	
	Violet	Orange	
	Violet-red	Orange-red	

Red.

It will be at once remarked, in considering these tables, that almost all flowers susceptible of changing colour only do it in general by rising or descending in the series to which they belong. Thus in the xanthic series, the flowers of Marvel of Peru may be yellow, orange-yellow, or red; those of the Austrian Rose, orange-yellow or orange-red; those of the Nasturtium vary from yellow to orange and orange-red; those of the Garden Ranunculus pass through every gradation in the series, from red, to green. As to the cyanic series, the Anemone varies from blue to violet and red; the Hyacinth from green to red through all the gradations; the Lithospermum purpureo-cæruleum from blue to violet-red: and the China Aster from violet-blue to violet, violet-red, and red.

Although there are certain exceptions to these rules, particularly in the Hyacinths, some of whose varieties approach the xanthic series, yet they are so far conformable to nature as to help us either in searching for the causes of colour, or in predicting the possible varieties of colour in flowers of the same species, and sometimes of the same genus.

Messrs. Schübler and Funk, considering green as the common colour of plants, have attempted to show that other colours are modifications of it, regarding all deviations as owing to the admixture of acid or alkaline secretions, an opinion in which they have been supported by Macaire Prinsep, whose views are adopted by De Candolle and others. But Macquart asserts (*Die Farben der Blüthen*, 1835) that the chemical theory of Macaire Prinsep is erroneous, and offers quite another explanation of the nature of the changes in vegetable living colours. To understand this, it is necessary to consider the general nature of vegetable fluids, and especially what is really the colouring matter of plants.

Crude sap is colourless, and to a certain extent it remains so to the end of the existence of a plant, filling the cells and many of the intercellular passages. But by degrees it becomes altered, and gains the green colour which is called *chlorophyll.* This is in some cases a mere gelatinous mass lining the cells, or arranging itself in certain definite forms in different plants: in transverse zones in Conferva zonata and others, in spiral bands in Spirogyra, and in the form of gelatinous threads in many succulent plants; or it acquires a distinctly granular appearance. In the latter case, Mohl states that it is uniformly collected round a grain of starch, which forms its nucleus, or round several grains, as may be ascertained by testing the chlorophyll with iodine. That this is often so, may be easily seen by any one accustomed to delicate microscopical investigations. But I do not find the starch constantly *inside* the grains of chlorophyll; on the contrary, it is certain that in some instances, as that of Cattleya Forbesii, they are *external* to the chlorophyll. I have counted as many as nine embedded in the circumference of a single grain of chlorophyll in this plant.

This chlorophyll, although so abundant in plants as to be the exclusive cause of their green colour, is nevertheless, according to Berzelius (*Comptes rendus*, vi. 644.), so economically distributed, that he is persuaded that there is not 3½ oz. (10 grammes) of it in all the leaves of a large tree. This great chemist states that it is infusible at 200°, when it begins to decompose; insoluble in water, moderately soluble in alcohol and ether. It is dissolved in concentrated sulphuric acid and in muriatic acid equally concentrated; water then precipitates it. The muriatic acid may be evaporated without destroying the chlorophyll. It gives definite combinations with bases, stains aluminated wool, shows evident signs of reduction and reoxidation, and is also very alterable by air and light.

It seems that all the other colours in plants are produced by alterations of chlorophyll. Macquart, while he entirely denies the existence of one series of oxidised yellow-red colours, and of another of disoxidised cyanic colours, asserts that the chlorophyll yields a blue colouring matter by abstraction of water, and a yellow colour by the addition of water. The blue matter, or *anthocyane*, is an extractive matter soluble in water but not in alcohol; is stained red by acids, and green by alkalies; it forms the basis of all blue, violet, red, brown, and many orange flowers; it is also found in all orange, violet, or blue leaves, and sometimes in roots that are not perennial. The yellow matter, or *anthoxanthine*, is an extractive resinous substance, partly soluble in water and partly in alcohol or ether, and it becomes blue by the action of sulphuric acid. These two colouring matters may be found in the same petal, but then they are contained in different cells, the anthoxanthine occurring in the lower cells, the anthocyane, on the contrary in the more superficial cells; and this produces a great variety in the colour of petals. The various hues of leaves are caused by the different states in which chlorophyll is found, and also by the presence of anthoxanthine, which Berzelius calls *xanthophyll.* Berzelius once thought that the latter was produced by chlorophyll under the influence of light, and that leaves become yellow when the secretion of chlorophyll ceases; but he abandoned that opinion upon finding that, when chlorophyll is exposed to sunlight until it becomes yellow, it is not xanthophyll.

Macquart supposes that the red colour so common in plants in the autumn is caused by the developement of anthocyane, which becomes red when acted upon by an acid; and not by any alteration in the chlorophyll itself. Mohl, however, doubts if this is always the case (*Ann. Sc.*, n. s., ix. 218.); he considers that, in numerous instances, the red tint gained by evergreen leaves in winter is owing to a change in their physical functions at that season, when the leaves attract little or no ascending sap, but exist at the expense of the matter already stored up in them. This is, however, a chemical, rather than a botanical question, and must not be treated of here at greater length.

With regard to white colour, it is by no means caused by the emptiness of tissue, as has been represented, but is owing to the colourless quality of the fluid contained in tissue. It may be doubted, indeed, whether it really exists in a state of purity in flowers, and it seems to be rather some other colour reduced to an exceedingly light tint. Redouté, the French flower-painter, is said to have availed himself with great advantage of this fact. He always placed the flower he wished to represent before a sheet of paper like that on which he had made his drawing, and he uniformly found that the flower would differ from the paper in being more yellow, or more pink, or more blue, or in some other way. White Campanulas become blue when they are dried; infusions of white flowers in alcohol have always a perceptible tinge. Flowers which are white, verging upon yellow, yield infusions which alkalies bring to a more decided yellow or a more positive brown; infusions of those which are white, tending to blue or red, become light red by the action of acids, and greenish by the action of alkalies.

If the white petals of Convolvulus tricolor are examined, their cells will appear quite empty. If weak sulphuric acid is applied to them, a slight cloudiness makes its appearance, but still there is nothing distinct enough to satisfy the observer that a colourless fluid is present: but, if iodine is then applied, the interior of the before colourless, and apparently empty, cells is filled with an olive-brown coagulum, among which round granules become distinctly visible. The rapid changes that white flowers undergo in a few hours offer similar evidence. Cheiranthus chamæleo has a flower at first of a whitish colour, which afterwards becomes lemon-yellow, then red, and slightly violet. Stylidium fruticosum has its young petals pale yellow, its old ones white tinged with red. The flowers of Œnothera tetraptera are at first whitish, afterwards pink, and finally red. The petals of the common Tamarind are said to be white the first day, and yellow the second. The corolla of Cobæa scandens is greenish-white the first day, and violet the next. Finally, Hibiscus mutabilis unfolds its blossoms in the morning white, by noon they are pink, and red at night. These changes are constant in the West Indies; but Ramon de la Sagra observed that, on the 19th of October, 1828, the flowers of this plant remained white all day in the garden at the Havannah, and did not become pink till noon the next day. Now this 19th of October was remarkable for the centigrade thermometer not rising higher than 19°, while the ordinary temperature of the flowering season of the Hibiscus is 30° centigr.; so that it would seem that heat has some important connection with the developement of colour; and this notion is in accordance with the fact, that white flowers are most common in cold countries. Korthals supposes he has ascertained experimentally that the change in the Hibiscus flowers from white to red is owing to oxygenation. (*An. Sc.*, n. s., ix. 63.)

All the brilliant spectacle of vegetable colours tends to disappear either in consequence of accidents or upon the approach of death: and what renders this subject the more curious is, 1. that discolouration is often determined by the same agents as in other cases produce colour; and 2. that certain organs which have no colour while alive gain when dead a very decided tint.

Solar light seems to be the most usual cause of those losses or changes of colours. While plants are alive, it acts, as we have so frequently seen, by colouring them: but in certain cases its too powerful action discolours them. Thus the cultivators of tulips place their flowers under a tent, knowing very well that the direct action of the sun tends to alter their colours more promptly than would be the case in the shade.

A great number of delicate flowers, particularly of those belonging to the cyanic series, exhibit this phenomenon.

Most aquatic plants gain in death a whitish hue; this is particularly remarked in sea-weeds, which, from the most brilliant blue or green, pass to white when they die, an effect which seems to be augmented when they are exposed to air and light; but the exact mode of action of these several agents has not been appreciated. Fresh-water Confervæ and several aquatic herbs present the same system of discolouration. Air evidently produces its effect by altering their chlorophyll, probably by abstracting its carbon; for such is the ordinary effect of the air upon dead vegetable matter. Charas, in particular, when dried in the air, become quite white; this tint is no doubt to be ascribed to the alteration of their chlorophyll, but in all probability also to the enormous quantity of calcareous matter that those plants, while alive, fix in their tissue; other cases of a like nature may be easily named. Most leaves when they die are invested with a uniform russet colour; it has some analogy with what happens in bletted fruits, such as the medlar. Such a state of the leaf may very well be owing, both in leaves and in fruits, to an alteration in their principles, analogous to putrefaction or fermentation. It is always accompanied with a great loss of water; but we have no direct evidence as to the nature of this change.

CHAPTER XVII.

OF ODOURS.

All that relates to the cause of odour in plants is enveloped in great obscurity, and will remain so till chemists shall have examined the subject much more carefully than hitherto. Our senses are daily gratified by the sweet perfumes exhaled by the leaves and flowers that surround us; and art exhausts its skill to preserve them by means which enable us always to have them present for our use; but as to the reasons why one kind of flower is odoriferous and another scentless, or why that which is perfumed in the evening is scentless at noon, we are still more in the dark than in what relates to colour. The facts connected with the enquiry have been well stated by De Candolle.

All odours are owing to the disengagement of volatile matter; and as there are few organised bodies in which, in their natural state, there is not some volatile constituent part, so neither are there many organic bodies absolutely destitute of smell. But it is only to cases in which the scent is very perceptible to our senses that we apply the idea of odoriferous, and it is consequently to those that we here confine ourselves; dividing them into *permanent*, *fugitive*, and *intermittent.*

Those odours are the most *permanent* in which the volatile matter is so enclosed in cells and concentrated as to disperse slowly. Of this many instances are afforded by wood and bark, which, being in truth the only permanent parts of vegetation, will of necessity be the receptacle of durable odours. Such parts are not scented, because of their own proper nature, for all the tissue of plants is originally scentless, or nearly so; but they owe their property to the fragrant secretions imprisoned in their cavities, and the permanence of their odour will be proportioned to the difficulty the volatile parts of their secretions experience in escaping through the tissue which encloses them, as well as to the degree in which the volatile matter may be fixed. Thus resinous woods, such as Cedar and Cypress, are fragrant for an indefinite period, because the resinous matter in which their odour resides is parted with slowly. Parts whose scent resides in essential oil preserve their scent for a long time, where the essential oil is but slightly volatile, or the wood is thick and hard: thus the Rose-wood of Teneriffe (not the Rose-wood of the English cabinet-makers), produced by Convolvulus scoparius, preserves its odour a very long time; and, in order to elicit it, it is necessary to rub the wood strongly, so as to produce heat enough to volatilise the matter which is locked up in the very compact tissue of which that plant consists. The necessity of producing a little heat, in order to produce an exhalation of the volatile matter, is further exemplified by the fragrance emitted by many woods, otherwise scentless, when exposed to the violent friction of a turner's lathe; Beech is said to acquire, under such circumstances, the smell of roses. But when, on the other hand, the volatile matter is enclosed in wood of a loose texture, neither is heat required to elicit it, nor has the wood, if exposed to the air, the power of retaining it for any considerable time, for the oxygen of the atmosphere will seize upon it rapidly, and quickly leave nothing behind but the inodorous tissue: this happens to Cassia and Cinnamon.

Fugitive smells are those which, belonging to perishable organs, are either extremely perishable in their very nature, or are placed in tissue of the laxest kind, or are situated on the surface of plants where their volatile parts are continually abstracted by the atmosphere, or finally are secreted in quantities so small that a short exposure to air suffices to dissipate them. All these odours are produced only during the life of a plant; they are dispersed as they are formed, and after death leave no trace of their existence behind them. Like permanent odours, these are continually given off; and in some plants, as the Orange and the Violet, without any variation in intensity in different states of the atmosphere; but in the majority of cases the power of the smell will vary according to the elevation of temperature, and the dampness of the air. This fact must be familiar to all who are acquainted with gardens. In the hot dry weather of a summer's noon, flowers either become scentless, or at least lose a large proportion of their usual fragrance; and, in walking through a wilderness of the most sweet-smelling plants, we find little sign of their odour, unless they are bruised or trampled upon. But if a heavy shower should come on, all will be changed in an hour's time; every leaf, every flower, will emit its peculiar odour; the Musk Plant (Mimulus moschatus) will fill the air with its singular scent, and it will be obvious that the addition of moisture to the air has produced a total change in the action of the odoriferous organs of plants.

The same phenomenon is daily repeated in the driest days of autumn. Those only who are accustomed to take their early walks abroad can have any idea of the difference between a richly stored garden early in the morning and at noon. When the sun has dried the air, and has been beating for some time upon vegetation, ill able to bear his action, in consequence of the dryness of the source from which it draws its means of compensating for evaporation, however beautiful a garden may still remain, it cannot be compared to the same place before the dew has dispersed; when every herb, tree, and flower is pouring forth a stream of the most varied and delicious fragrance; when the air is impregnated with the most delicate balsamic odours; and when all nature seems as if offering up incense in gratitude for the refreshing powers of darkness and of dew. Let any one, for example, visit a thicket of Cistuses at noon, and again the next morning, and the difference will be exceedingly apparent. To what cause this is owing is unknown; possibly the effect of dryness and excessive heat may be to close the stomates, and to contract the tissue of plants, thus rendering it difficult for volatile matter to pass through their cuticle: it may also act by depriving them of the necessary proportion of water required to enable them to perform their functions of secretion and assimilation, and thus arrest for a time the elaboration of the fugitive principles upon which fragrance depends. While, however, dew and showers, with intervals of bright light, are eminently favourable to the eliciting of vegetable perfumes, a continuance of wet and gloomy weather, without much sunshine, is as greatly unfavourable. This latter circumstance is explicable upon the general law of physiology, that secretions cannot be readily produced without the direct assistance of the sun's light.

With regard to what we call *intermittent* odours, no explanation seems possible in the present state of our knowledge. A few examples of them will therefore be all that we can give. All dingy-flowered plants, such as botanists call *tristes*, belong to this class; such as the Pelargonium triste, Hesperis tristis, Gladiolus tristis, which are almost entirely scentless during the day, but become deliciously fragrant at night. Great numbers of Orchideous plants have flowers possessing the same property: the Catasetums have a fine aromatic odour at night, none in the day, except C. purum; Cymbidium sinense is also chiefly fragrant at night; and so with a great many more. Cestrum nocturnum is another plant of the same nature; in the day it has no odour, at night its perfume is extremely powerful. One of the most singular instances of exceptions to all rules appears to be referable to this class: Cacalia septentrionalis exhales an aromatic odour if exposed to the direct rays of the sun; and if any thing is interposed between it and the sun its odour disappears, but is renewed as soon as the interference is removed.

The best observations upon intermittent odours, that I know of, are those of Morren (*Observations sur l'Anatomie et la Physiologie de la Fleur du Cereus grandiflorus*). He states that in this plant the fragrance is not traceable to any glandular apparatus, or to some reservoir of secretions, but that it is strictly functional, a vital action of the organs of fructification. The fragrance is evidently formed in the organs that part with it; for when an unexpanded flower was cut in two in the morning, being at that time scentless, it became fragrant towards 7 o'clock in the evening. " The odour is undoubtedly formed in each cell of parenchyma by a particular process." It is the property of the Cereus flower to part with its fragrance at intervals only. Morren observed in one case of a cut flower, that it gave off puffs of odour every half hour, from 8 to 12

p. m., when it faded, and the smell became very slight. On another occasion, when the flower was left on the plant, it began to expand at 6 p. m., when the first fragrance was perceptible in the greenhouse. A quarter of an hour afterwards the first puff of odour took place, after a rapid motion of the calyx: in rather less than a second quarter of an hour another powerful emanation of fragrance took place: by 35 minutes past 6 the flower was completely open: at a quarter to 7 the odour of the calyx was the strongest, but modified by the petals: after this time the emanations of odour took place at the same periods as before. Morren considers it probable that these exhalations are periodical, because the emission of carbonic acid by the same organs takes place also in an intermittent manner, and that the emanations of fragrance are a sign of the respiration of the flower.

BOOK III.

GLOSSOLOGY; OR, OF THE TERMS USED IN BOTANY.

In order to comprehend the language of botanists, it is necessary that the unusual terms or words which are employed in writing upon the subject, and which are either different from words in vulgar use, or which are in Botany employed in a particular sense, should be fully explained.

It is a very common plan to mix up Glossology with Organography, or to confound the definition and explanation of those characteristic terms of the science which are universally applicable, with the description of particular organs: but this plan is attended with many inconveniences, and is far less simple than to treat of the two separately. It was an error into which Linnæus fell, in composing his admirable *Philosophia Botanica;* and is the more remarkable, if the logical precision with which that work is otherwise composed be considered. Instead of distinguishing those terms which have a general application to all plants or parts of plants, according to circumstances, from such as have a particular application, and relate only to special modifications, he placed under his definition of each organ those terms which he knew to be applicable to it; but, as it was not his practice to repeat terms after they had been once explained, it frequently happened that beginners in the science, finding a given term explained once only, and with reference to a particular organ, fell into the mistake of supposing that that term was applicable only to the organ under which it was explained. To avoid this difficulty, other botanists have collected under each organ all the terms which could by possibility be applied to it, and have repeated them over and over again without regard to previous definitions; as if they supposed it impossible to convey by words an idea of the meaning of any term whatever, without noticing at length every possible application of it. Thus, in Willdenow's *Principles of Botany*, the most common and simple terms are repeated five, six, and even seven times; and in a more modern work, of very high character (*Les E'lémens de Physiologie Végétale et de Botanique*, by Mirbel), the same practice has been carried so far, that the application of the word *simple* is explained in twenty-three different instances.

The true principles of arranging the glossology of science have, however, been long before the public. In the year 1797, Link, in his *Prodromus Philosophiæ Botanicæ*, distinguished the characteristic or common terms used in Botany from those which applied only to particular organs; and his example was afterwards followed by Illiger, a learned German naturalist, who, in the year 1810, proposed a total reformation of the method of describing the terms employed in Natural History (see his *Versuch einer Systematischen vollständigen Terminologie für das Thierreich und Pflanzenreich*). Little attention, however, was paid to the principles of these writers till the year 1813; when De Candolle adopted them in his *Théorie E'lémentaire de la Botanique*, with his accustomed skill and sagacity.

The characteristic terms of Botany are those which have a general application to any or all of the parts of plants, and must not be confounded with such as have a particular application only, which will be found under the organs to which they respectively belong: the former are either *individual* or *collective*; of which the first apply to plants, or parts of plants, considered abstractedly; the second to plants, or their parts, considered in masses. To these are to be added those syllables and marks which, either prefixed or affixed to a known term, occasion an alteration in its signification. These I call *terms of qualification*. In the following arrangement, those terms which are seldom used are marked with a †; and those are entirely omitted which are used in Botany in their common acceptation.

CHARACTERISTIC TERMS are either INDIVIDUAL or COLLECTIVE.

- CHARACTERISTIC INDIVIDUAL TERMS are either *Absolute* or *Relative*.
  - *Characteristic Individual Absolute Terms* relate to, —
    1. *Figure.*
       - A. with respect to general form.
       - B. outline.
       - C. the apex or point.
    2. *Division.*
       - A. with respect to the margin.
       - B. incision.
       - C. composition or ramification.
    3. *Surface.*
       - A. with respect to marking or evenness.
       - B. appendages.
       - C. polish.
    4. *Texture.*
    5. *Size.*
    6. *Duration.*
    7. *Colour.*
    8. *Variegation.*
    9. *Veining.*
  - *Characteristic Individual Relative Terms* comprehend, —
    1. *Estivation.*
    2. *Direction.*
    3. *Insertion.*
       - A. with respect to the mode of attachment or of adhesion.
       - B. situation.
  - *Characteristic Collective Terms* relate to, —
    1. *Arrangement.*
    2. *Number.*

Class I. OF INDIVIDUAL TERMS.

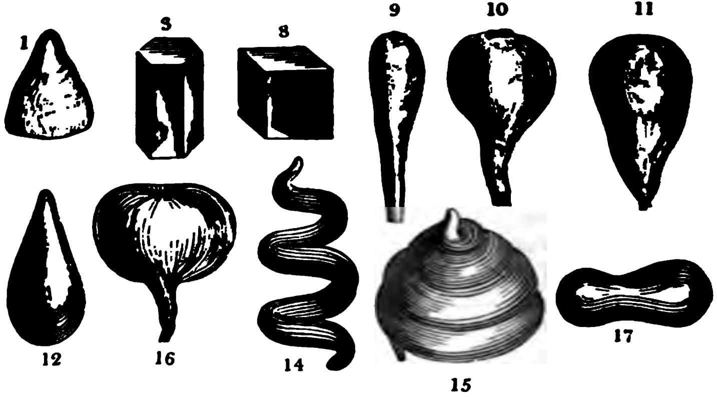
The terms which are included in this class are applied to the parts of a plant considered by themselves, and not in masses: they are either *absolute*, being used with reference to their own individual quality; or *relative*, being employed to express the relation which is borne by plants, or their parts, to some other body. Thus, for example, when we say that a plant has a *lateral ovate* spike of flowers, the term *lateral* is relative, being used to express the relation which the spike bears to the stem; and the term *ovate* is absolute, being expressive of the actual form of the spike: and, again, in speaking of a *rugose terminal* capsule, *rugose* is absolute, *terminal* is relative.

I. *Of Individual Absolute Terms.*

These relate to figure, division, surface, texture, size, duration, colour, variegation, and veining.

1. Of Figure.

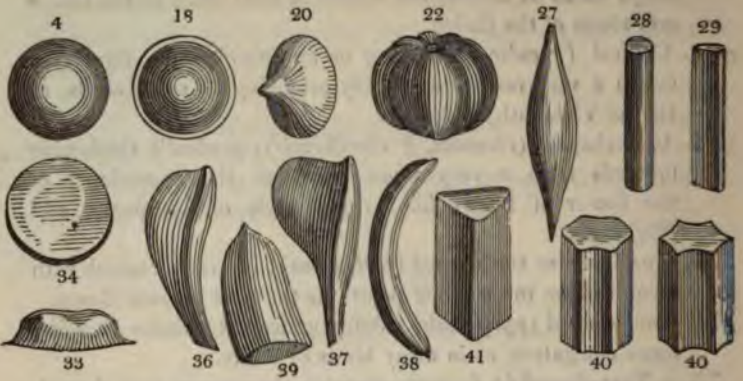
A. *With respect to general Form.*



1. Conical (*conicus*, † *pyramidalis*); having the figure of a true cone; as the prickles of some Roses, the root of Carrot, &c.
2. Conoidal (*conoideus*); resembling a conical figure, but not truly one; as the calyx of Silene conoidea.
3. Prism-shaped (*prismaticus*); having several longitudinal angles and intermediate flat faces; as the calyx of Frankenia pulverulenta.
4. Globose (*globosus*, *sphæricus*, † *globulosus*); forming nearly a true sphere; as the fruit of Ligustrum vulgare, many seeds, &c.
5. Cylindrical (*cylindricus*); having nearly a true cylindrical figure: as the stems of Grasses, and of most monocotyledonous plants.
6. Tubular (*tubulosus*, † *tubulatus*); approaching a cylindrical figure, and hollow; as the calyx of many Silenes, &c.
7. Fistulous (*fistulosus*); this is said of a cylindrical or terete

body, which is hollow, but closed at each end; as the leaves and stems of the Onion.

8. Cubical († *cubicus*); having or approaching the form of a cube: a very rare form, chiefly occurring in some seeds, as that of Vicia lathyroides.
9. Club-shaped (*clavatus*, † *claviformis*); gradually thickening upwards from a very taper base; as the appendages of the flower of Schwenkia, or the style of Campanula and Michauxia.
10. Turbinate, or top-shaped (*turbinatus*); inversely conical, with a contraction towards the point; as the fruit of some Roses.
11. Pear-shaped (*pyriformis*); differing from turbinate in being more elongated; as in many kinds of Pears.
12. † Tear-shaped († *lachrymæformis*); the same as pear-shaped, except that the sides of the inverted cone are not contracted; as the seed of the Apple.
13. † Strombus-shaped († *strombuliformis*); twisted in a long spire, so as to resemble the convolutions of the shell called a Strombus; as the pod of Acacia strombulifera, or Medicago polymorpha.
14. Spiral (*spiralis*); twisted like a corkscrew.
15. Cochleate (*cochleatus*); twisted in a short spire, so as to resemble the convolutions of a snail-shell; as the pod of Medicago cochleata, the seed of Salicornia.
16. Turnip-shaped (*napiformis*); having the figure of a depressed sphere; as the root of the Turnip-Radish, &c.
17. † Placenta-shaped († *placentiformis*); thick, round, and concave, both on the upper and lower surface; as the root of Cyclamen.
18. Lens-shaped (*lenticularis, lentiformis*); resembling a double convex lens; as the seeds of Amaranthus.
19. Buckler-shaped (*scutatus, scutiformis*); having the figure of a small round buckler; as the scales upon the leaves of Elæagnus: lens-shaped, with an elevated rim.
20. Bossed (*umbonatus*); round, with a projecting point in the centre, like the boss of an ancient shield; as the pileus of many species of Agaricus.
21. Gibbous (*gibbus, gibbosus*); very convex or tumid; as the leaves of many succulent plants: properly speaking, this term should be restricted to solid convexities.
22. † Melon-shaped († *meloniformis*); irregularly spherical, with projecting ribs; as the stem of Cactus Melocactus: a bad term.



23. Spheroidal (*sphæroideus*); a solid with a spherical figure, a little depressed at each end. *De Cand.*

24. Ellipsoidal (*ellipsoideus*); a solid with an elliptical figure. *De Cand.*

25. Ovoidal (*ovoideus*); a solid with an ovate figure, or resembling an egg. *De Cand.*

26. Shield-shaped (*clypeatus*); in the form of an ancient buckler: the same as scutate, No. 19.

27. Spindle-shaped (*fusiformis*, †*fusinus*); thick, tapering to each end; as the root of the long Radish. Sometimes conical roots are called fusiform, but improperly.

28. Terete, or taper (*teres*); the opposite of angular: usually employed in contradistinction to that term, when speaking of long bodies. Many stems are terete.

29. Half-terete (*semiteres*); flat on one side, terete on the other.

30. Compressed (*compressus*); flattened lengthwise; as the pod of a Pea.

31. Depressed (*depressus*); flattened vertically; as the root of a Turnip.

32. Plane (*planus*); a perfectly level or flat surface; as that of many leaves.

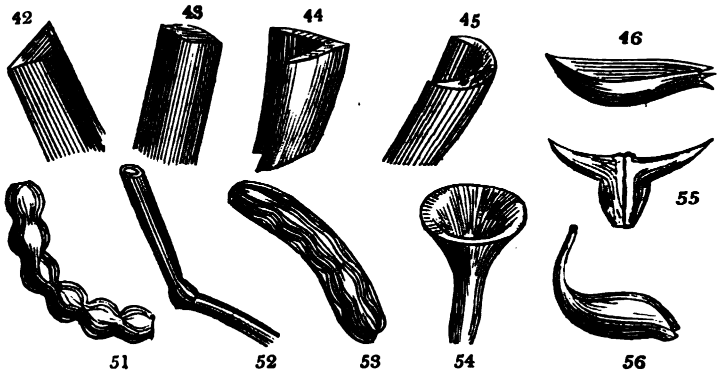
33. Cushioned (*pulvinatus*); convex, or rather flattened: seldom used.

34. Discoidal (*discoideus*); orbicular, with some perceptible thickness, parallel faces, and a rounded border; as the fruit of Strychnos Nux-vomica.

35. Curved (*arcuatus*, *curvatus*); bent, but so as to represent the

arc of a circle; as the fruit of Astragalus hamosus, Medicago falcata, &c.

36. Scimitar-shaped (*acinaciformis*); curved, fleshy, plane on the two sides, the concave border thick, the convex border thin; as the leaves of Mesembryanthemum acinaciforme.
37. Axe-shaped (*dolabriformis*); fleshy, nearly straight, somewhat terete at the base, compressed towards the upper end; one border thick and straight, the other enlarged, convex, and thin; as the leaves of Mesembryanthemum dolabriforme.
38. Falcate (*falcatus*); plane and curved, with parallel edges, like the blade of a reaper's sickle; as the pod of Medicago falcata: any degree of curvature, with parallel edges, receives this name.
39. Tongue-shaped (*linguiformis*); long, fleshy, plano-convex, obtuse; as the leaves of Sempervivum tectorum, and some Aloes.
40. Angular (*angulosus*); having projecting longitudinal angles. We say *obtuse-angled* when the angles are rounded, as in the stem of Salvia pratensis; and *acute-angled* when they are sharp, as in many Carices. Some call these angles the *acies*.
41. Three-cornered (*trigonus*); having three longitudinal angles and three plane faces; as the stem of Carex acuta.
42. Three-edged (*triangularis, triqueter*); having three acute angles with concave faces, as the stems of many plants; generally used as a synonyme of trigonus.
43. Two-edged (*anceps*); compressed, with two sharp edges; as the stem of an Iris.
44. Keeled (*carinatus*); formed in the manner of the keel of a boat; that is to say, with a sharp projecting ridge, arising from a flat or concave central rib; as the glumes of Grasses.
45. Channelled (*canaliculatus*); long and concave, so as to resemble a gutter or channel; as the leaves of Lygeum Spartum, Tradescantia virginica, &c.
46. Boat-shaped (*cymbiformis, navicularis*); having the figure of a boat in miniature; that is to say, concave, tapering to each end, with a keel externally; as the glumes of Phalaris canariensis: scarcely different from 44.
47. Whip-shaped (*flagelliformis*); long, taper, and supple, like the thong of a whip; as the stem of Vinca, and of many plants. This term is confined to stems and roots.



48. Rope-shaped (*funalis*, † *funiliformis*); formed of coarse fibres resembling cords; as the roots of Pandanus, and other arborescent monocotyledons. *Mirbel.*

49. Thread-shaped (*filiformis*); slender like a thread; as the filaments of most plants, and the styles of many.

50. Hair-shaped (*capillaris*); the same as filiform, but more delicate, so as to resemble a hair: it is also applied to the fine ramifications of the inflorescence of some plants; as Grasses.

51. Necklace-shaped (*moniliformis*, † *nodosus*, Mirb.); cylindrical or terete, and contracted at regular intervals; as the pods of Sophora japonica, Ornithopus perpusillus, &c., the hairs of Dicksonia arborescens, &c.

52. Worm-shaped (*vermicularis*); thick, and almost cylindrical, but bent in different places; as the roots of Polygonum Bistorta. *Willd.*

53. Knotted (*torulosus*); a cylindrical body, uneven in surface; as the pod of Chelidonium: this is very nearly the same as moniliform.

54. Trumpet-shaped (*tubæformis*, *tubatus*); hollow, and dilated at one extremity, like the end of a trumpet, *De Cand.*; as the corolla of Caprifolium sempervirens.

55. Horned (*cornutus*, *corniculatus*); terminating in a process resembling a horn; as the fruit of Trapa bicornis. If there are two horns, the word *bicornis* is used; if three, *tricornis*; and so on.

56. Beaked (*proboscideus*); having a hard terminal horn; as the fruit of Martynia.

57. Crested (*cristatus*); having an elevated, irregular, or notched ridge, resembling the crest of a helmet. This term is chiefly

applied to seeds, and to the appendages of the anthers of some Ericæ; such as E. triflora and comosa.

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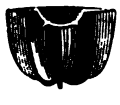

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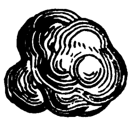

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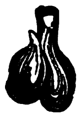

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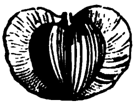

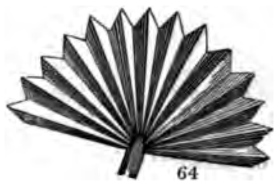

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58. Petal-like (*petaloideus*); having the colour and texture of a petal; as one lobe of the calyx of Mussænda, the bracteæ of many plants, the stamen of Canna, the stigmata of Iris.

59. Leaf-like (*foliaceus*, † *foliiformis*, † *phylloideus*); having the texture or form of a leaf; as the lobes of the calyx of Rosa, the apex of the fruit of Fraxinus, the persistent petals of Melanorrhœa.

60. Winged (*alatus*); having a thin broad margin; as the fruit of Paliurus australis, the seed of Malcomia, Bignonia, &c. In composition *pterus* is used; as *dipterus* for two-winged, *tripterus* for three-winged, *tetrapterus* for four-winged, &c.; *peripterus* when the wing surrounds any thing; *epipterus* when it terminates.

61. † Mill-sail-shaped († *molendinaceus*); having many wings projecting from a convex surface; as the fruit of some umbelliferous plants, and of Moringa.

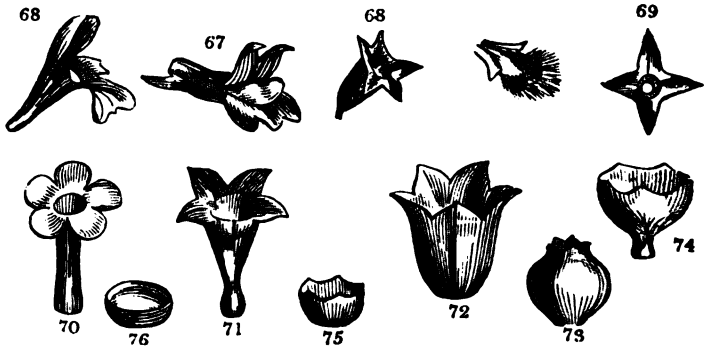
62. † Knob-like († *gongylodes*); having an irregular roundish figure.

63. Halved (*dimidiatus*); only half, or partially, formed. A leaf is called dimidiate when one side only is perfect; an anther when one lobe only is perfect; and so on.

64. Fan-shaped (*flabelliformis*); plaited like the rays of a fan; as the leaf of Borassus flabelliformis.

65. Grumous (*grumosus*); in form of little clustered grains; as the root of Neottia Nidus-avis, *Mirb.*; rather as the fæcula in the stem of the Sago Palm.

66. † Testicular († *testiculatus*); having the figure of two oblong bodies; as the roots of Orchis mascula.



67. Ringent, or personate (*ringens, personatus*); a term applied to a monopetalous corolla, the limb of which is unequally divided; the upper division, or lip, being arched; the lower prominent, and pressed against it, so that when compressed, the whole resembles the mouth of a gaping animal; as the corolla of Antirrhinum.

68. Labiate (*labiatus*); a term applied to a monopetalous calyx or corolla, which is separated into two unequal divisions; the one anterior, and the other posterior, with respect to the axis: hence bilabiate is more commonly used than labiate. Salvia and many other plants afford examples. It is often employed instead of ringent.

69. Wheel-shaped (*rotatus*); a calyx or corolla, or other organ, of which the tube is very short, and the segments spreading; as the corolla of Veronica and Galium.

70. Salver-shaped (*hypocrateriformis*); a calyx or corolla, or other organ, of which the tube is long and slender, and the limb flat; as in Phlox.

71. Funnel-shaped (*infundibularis, infundibuliformis*); a calyx or corolla, or other organ, in which the tube is obconical, gradually enlarging upwards into the limb, so that the whole resembles a funnel; as the corolla of Nicotiana.

72. Bell-shaped (*campanulatus*, †*campanaceus*, †*campaniformis*); a calyx, corolla, or other organ, in which the tube is inflated, and gradually enlarged into a limb, the base not being conical; as the corolla of Campanula.

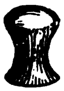
73. Pitcher-shaped (*urceolatus*); the same as campanulate, but more contracted at the orifice, with an erect limb; as the corolla of Vaccinium Myrtillus.

74. Cup-shaped (*cyathiformis*); the same as pitcher-shaped, but

not contracted at the margin; the whole resembling a drinking-cup; as the limb of the corolla of Symphytum.

75. † Cupola-shaped († *cupuliformis*); slightly concave, with a nearly entire margin; as the calyx of Citrus, or the cup of an acorn.

76. Kneepan-shaped (*patelliformis*); broad, round, thick; convex on the lower surface, concave on the other: the same as *meniscoideus*, but thicker. The embryo of Flagellaria indica is patelliform.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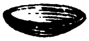
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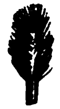
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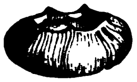
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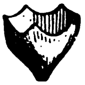
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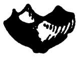
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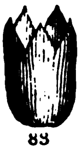
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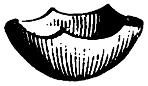
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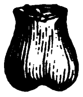
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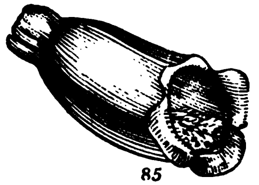
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77. † Pulley-shaped († *trochlearis*); circular, compressed, contracted in the middle of its circumference, so as to resemble a pulley; as the embryo of Commelina communis.

78. Scutelliform (*scutelliformis*); the same as patelliform, but oval; not round, as the embryo of Grapes.

79. Brush-shaped († *muscariformis*); formed like a brush or broom; that it to say, furnished with long hairs towards one end of a slender body; as the style and stigma of many Compositæ.

80. Acetabuliform (*acetabuliformis*, † *acetabuleus*); concave, depressed, round, with a border a little turned inwards; as the fruit of some Lichens.

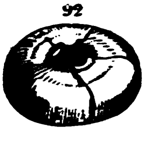
81. † Goblet-shaped († *crateriformis*); concave, hemispherical, a little contracted at the base; as some Pezizas.

82. † Cotyliform († *cotyliform*); resembling *rotate*, but with an erect limb.

83. † Poculiform († *poculiformis*); cup-shaped, with a hemispherical base and an upright limb; nearly the same as campanulate.

84. † Pouch-shaped († *scrotiformis*); hollow, and resembling a little double bag; as the spur of many Orchises.

85. † Foxglove-shaped († *digitaliformis*); like campanulate, but longer, and irregular; as the corolla of Digitalis.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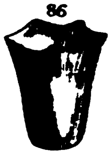
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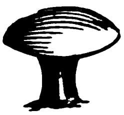
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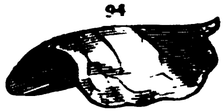
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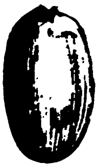
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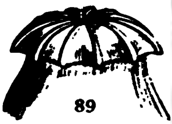
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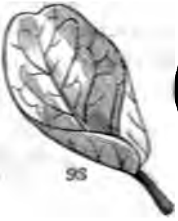
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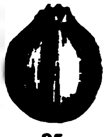
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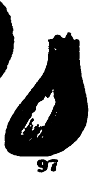
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86. † Vase-shaped († *vascularis*); formed like a flower-pot; that is to say, resembling an inverted truncate cone.

87. † Tapeworm-shaped († *tæniamus*); long, cylindrical, contracted in various places, in the manner of the tapeworm.

88. † Sausage-shaped († *botuliformis*); long, cylindrical, hollow, curved inwards at each end; as the corolla of some Ericas.

89. † Umbrella-shaped († *umbraculiformis*); resembling an expanded umbrella; that is to say, hemispherical and convex, with rays, or plaits, proceeding from a common centre; as the stigma of Poppy.

90. † Meniscoid († *meniscoideus*); thin, concavo-convex, and hemispherical, resembling a watch-glass.

91. Mushroom-headed (*fungiformis, fungilliformis*); cylindrical, having a rounded, convex, overhanging extremity; as the embryo of some monocotyledonous plants, as Musa.

92. † Nave-shaped († *modioliformis*); hollow, round, depressed, with a very narrow orifice; as the ripe fruit of Gaultheria.

93. Hooded (*cucullatus*); a plane body, the apex or sides of which are curved inwards, so as to resemble the point of a slipper, or a hood; as the leaves of Pelargonium cucullatum, the spatha of Arum, the labellum of Pharus.

94. † Saddle-shaped (*sellæformis*); oblong, with the sides hanging down, like the laps of a saddle; as the labellum of Cattleya Loddigesii.

95. Turgid (*turgidus*); slightly swelling.

96. Bladdery (*inflatus*); thin, membranous, slightly transparent, swelling equally, as if inflated with air; as the calyx of Cucubalus.

97. Bellying (*ventricosus*); swelling unequally on one side; as the corolla of many labiate and personate plants.

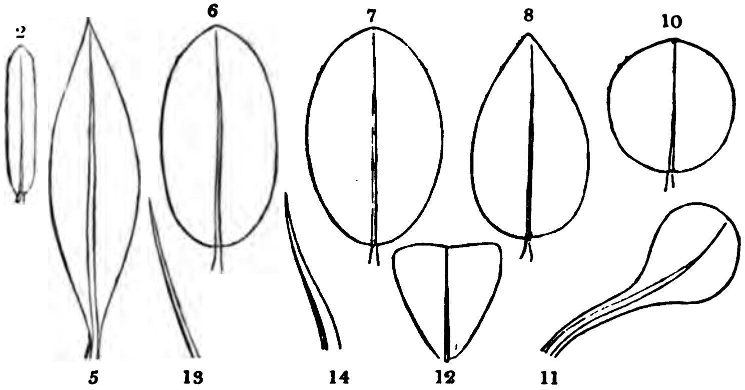
98. Regular (*regularis*); in which all the parts are symmetrical. A rotate corolla is regular; the flower of a Cherry is regular.

99. Irregular (*irregularis*); in which symmetry is destroyed by some inequality of parts. A labiate corolla, and the flowers of the Horsechestnut and the Violet, are irregular.

100. Abnormal (*abnormis*); in which some departure takes place from the ordinary structure of the family or genus to which a given plant belongs. Thus, Nicotiana multivalvis, in which the ovarium has many cells instead of two, is unusual or abnormal.

101. Normal (*normalis*); in which the ordinary structure peculiar to the family or genus of a given plant is in nowise departed from.

B. *With respect to Outline.*



1. Outline (*ambitus, circumscriptio*); the figure represented by the margin of a body.

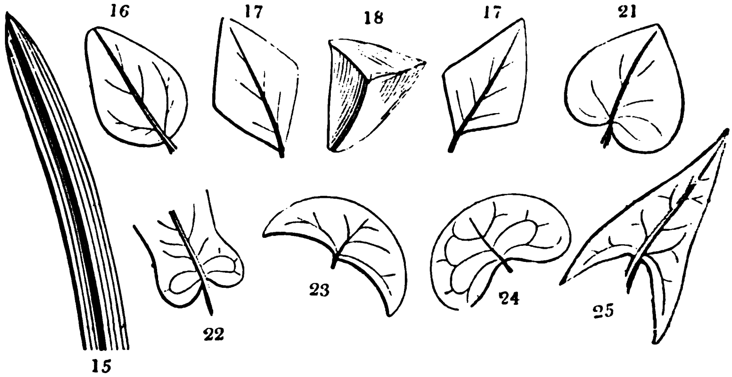
2. Linear (*linearis*); narrow, short, with the two opposite margins parallel; as the leaf of the Taxus.

3. † Band-shaped († *fasciarius*); narrow, very long, with the two opposite margins parallel; as the leaves of Zostera marina.

4. Strap-shaped (*ligulatus, loratus*); narrow, moderately long, with the two opposite margins parallel; as the leaves of Amaryllis equestris.

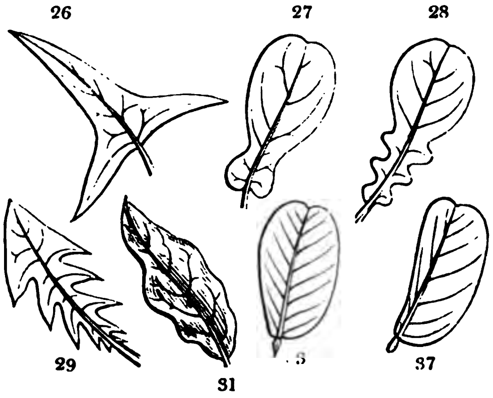
5. Lanceolate (*lanceolatus*); narrowly elliptical, tapering to each end; as the leaf of Plantago lanceolata, Daphne Mezereum, &c.

6. Oblong (*oblongus*); elliptical, obtuse at each end; as the leaf of the Hazel.
7. Oval (*ovalis*, *ellipticus*); elliptical, acute at each end; as the leaf of Cornus sanguinea.
8. Ovate, or † egg-shaped (*ovatus*); oblong or elliptical, broadest at the lower end, so as to resemble the longitudinal section of an egg; as the leaf of Stellaria media.
9. Orbicular (*orbicularis*); perfectly circular; as the leaf of Cotyledon orbiculare.
10. Roundish (*rotundus*, *subrotundus*, *rotundatus*); orbicular, a little inclining to be oblong; as the leaf of Lysimachia Nummularia, Mentha rotundifolia.
11. Spatulate (*spatulatus*); oblong, with the lower end very much attenuated, so that the whole resembles a chemist's spatula; as the leaf of Bellis perennis.
12. Wedge-shaped (*cuneatus*, *cuneiformis*, † *cunearius*); inversely triangular, with rounded angles; as the leaf of Saxifraga tridentata.
13. Awl-shaped (*subulatus*); linear, very narrow, tapering to a very fine point from a broadish base; as the leaves of Arenaria tenuifolia, Ulex europæus.
14. Needle-shaped (*acerosus*); linear, rigid, tapering to a fine point from a narrow base; as the leaves of Juniperus communis.



15. Sword-shaped (*ensiformis*, *gladiatus*); lorate, quite straight, with the point acute; as the leaf of an Iris.
16. † Parabolical († *parabolicus*); between ovate and elliptical, the apex being obtuse; as the leaf of Amaranthus Blitum.

17. Rhomboid (*rhombeus, rhomboideus*); oval, a little angular in the middle; as the leaf of Hibiscus rhombifolius.
18. Deltoid (*deltoides*); a solid, the transverse section of which has a triangular outline, like the Greek Δ: as the leaf of Mesembryanthemum deltoideum.
19. Triangular (*triangularis*); having the figure of a triangle of any kind; as the leaf of Betula alba.
20. Trapeziform (*trapeziformis, trapezoideus*); having four edges, those which are opposite not being parallel; as the leaf of Adiantum trapeziforme, Populus nigra.
21. Heart-shaped (*cordatus, cordiformis*); having two round lobes at the base, the whole resembling the heart in a pack of cards; as the leaf of Alnus cordifolia.
22. Eared (*auriculatus*); having two small rounded lobes at the base; as the leaf of Salvia officinalis.
23. Crescent-shaped (*lunatus, lunulatus, † semilunatus*); resembling the figure of the crescent; as the glandular apex of the involucral leaves of many Euphorbias.
24. Kidney-shaped (*reniformis, † renarius*); resembling the figure of a kidney; that is to say, crescent-shaped, with the ends rounded; as the leaf of Asarum europæum.
25. Arrow-headed (*sagittatus*); gradually enlarged at the base into two acute straight lobes, like the head of an arrow; as the leaf of Rumex Acetosella.



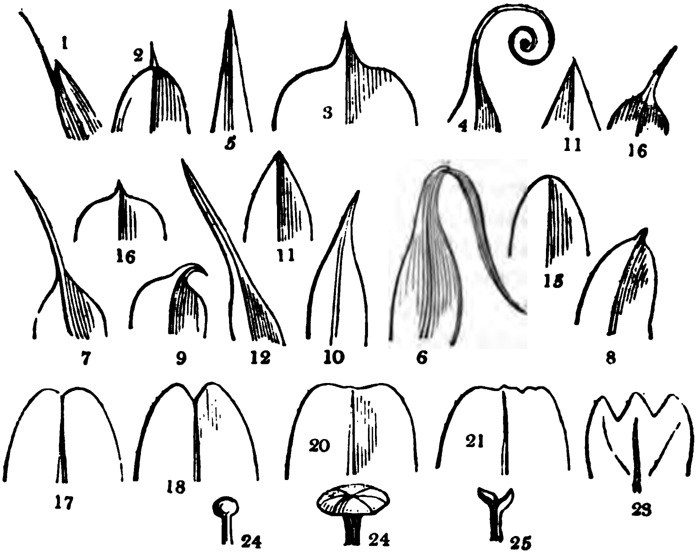
26. Halbert-headed (*hastatus*); abruptly enlarged at the base into two acute diverging lobes, like the head of a halbert; as the leaf of Arum maculatum.
27. Fiddle-shaped (*panduratus, panduriformis*); obovate, with a

deep recess or sinus on each side; as the leaves of Rumex pulcher.

28. Lyre-shaped (*lyratus*); the same as panduriform, but with several sinuses on each side, which gradually diminish in size to the base; as the leaf of Geum urbanum, Raphanus Raphanistrum.
29. Runcinate, or hook-backed (*runcinatus*); curved in a direction from the apex to the base; as the leaf of Leontodon Taraxacum.
30. Tapering (*attenuatus*); gradually diminishing in breadth.
31. Wavy (*undulatus*); having an uneven, alternately convex and concave margin; as the Holly leaf.
32. Equal (*æqualis*); when both sides of a figure are symmetrical; as the leaf of an Apple.
33. Unequal (*inæqualis*); when the two sides of a figure are not symmetrical; as the leaf of Begonia.
34. Equal-sided (*æquilaterus*); the same as equal.
35. Unequal-sided (*inæquilaterus*); the same as unequal.
36. Oblique (*obliquus*); when the degree of inequality in the two sides is slight.
37. Halved (*dimidiatus*); when the degree of inequality is so great that one half of the figure is either wholly or nearly wanting; as the leaf of many Bryonias.

C. *With respect to the Apex, or Point.*

1. Awned (*aristatus*); abruptly terminated in a hard, straight, subulate point of various lengths; as the paleæ of Grasses. The arista is always a continuation of the costa, and sometimes separates from the lamina below the apex.
2. Mucronate (*mucronatus*); abruptly terminated by a hard short point; as the leaf of Statice mucronata.
3. Cuspidate (*cuspidatus*); tapering gradually into a rigid point. It is also used sometimes to express abruptly acuminate; as the leaf of many Rubi.
4. Cirrhous (*cirrhosus, apice circinatus*); terminated by a spiral, or flexuose, filiform appendage; as the leaf of Gloriosa superba. This is due to an elongation of a costa.
5. Pungent (*pungens*); terminating gradually in a hard sharp point; as the leaves of Ruscus aculeatus.
6. Bristle-pointed (*setosus*, † *setiger*); terminating gradually in a very fine sharp point; as the leaves of many Mosses.
7. Hair-pointed (*piliferus*); terminating in a very fine weak point; as the leaves of many Mosses.

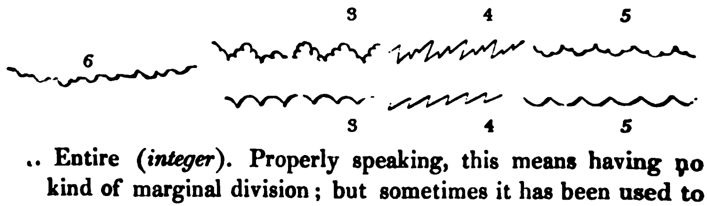


8. Pointleted (*apiculatus*); terminating abruptly in a little point; differing from mucronate in the point being part of the limb, and not arising wholly from a costa.
9. Hooked (*uncinatus*, † *uncatus*); curved suddenly back at the point; as the leaves of Mesembryanthemum uncinatum.
10. Beaked (*rostratus*, *rostellatus*); terminating gradually in a hard, long, straight point; as the pod of Radish.
11. Acute, or sharp-pointed (*acutus*); terminating at once in a point, not abruptly, but without tapering in any degree; as any lanceolate leaf.
12. Taper-pointed (*acuminatus*); terminating very gradually in a point; as the leaf of Salix alba.
13. † Acuminose († *acuminosus*); terminating gradually in a flat narrow end.
14. Tail-pointed (*caudatus*); excessively acuminated, so that the point is long and weak, like the tail of some animal; as the calyx of Aristolochia trilobata, the petals of Brassia caudata.
15. Blunt (*obtusus*); terminating gradually in a rounded end; as the leaf of Berberis vulgaris.
16. Blunt with a point (*obtusus cum acumine*); terminating abruptly in a round end, the middle of which is suddenly lengthened into a point; as the leaf of many Rubi.
17. Retuse (*retusus*); terminating in a round end, the centre of which is depressed; as the leaf of Vaccinium Vitis Idæa.

18. Emarginate (*emarginatus*); having a notch at the end, as if a piece had been taken out; as the leaf of Buxus sempervirens.
19. † *Accisus;* when the end has an acute sinus between two rounded angles. *Link.*
20. Truncate (*truncatus*); terminating very abruptly, as if a piece had been cut off; as the leaf of Liriodendron tulipifera.
21. Bitten (*præmorsus*, † *succisus*); the same as truncate, except that the termination is ragged and irregular, as if bitten off: the term is generally applied to roots; the leaf of Caryota urens is another instance.
22. † Dædaleous († *dædaleus*); when the point has a large circuit, but is truncated and rugged. *W.*
23. Trident-pointed (*tridentatus*); when the point is truncated, and has three indentations (*W.*); as Saxifraga tridentata, Potentilla tridentata.
24. Headed (*capitatus*); suddenly much thicker at the point than in any other part; a term confined to cylindrical or terete bodies; as Mucor, glandular hairs, &c.
25. Lamellar (*lamellatus*, *lamellosus*); having two little plates at the point; as the style of many plants.
26. † Blunt († *hebetatus*, De Cand.); having a soft obtuse termination.
27. Pointless (*muticus*). This term is employed only in contradistinction to some other that indicates being pointed; thus, if, in contrasting two things, one were said to be mucronate, the other, if it had not a mucro, would be called pointless: and the same term would be equally employed in contrast with cuspidate or aristate, or any such. It is also used absolutely.

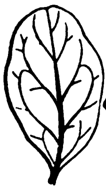
2. Of Division.

A. *With respect to the Margin.*



.. Entire (*integer*). Properly speaking, this means having no kind of marginal division; but sometimes it has been used to indicate not pinnatifid, and also nearly destitute of marginal division.
2. Quite entire (*integerrimus*); perfectly free from division of the margin.

3. Crenated (*crenatus*); having convex teeth. When these teeth are themselves crenated, we say *bicrenate.*
4. Sawed (*serratus*); having sharp straight-edged teeth pointing to the apex. When these teeth are themselves serrate, we say *biserrate*, or *duplicato-serrate.*
5. Toothed (*dentatus*); having sharp teeth with concave edges. When these teeth are themselves toothed, we say *duplicato-dentate*, or doubly toothed, but not *bidentate*, which means two-toothed.
6. Gnawed (*erosus*); having the margin irregularly toothed, as if bitten by some animal.
7. Curled (*crispus*); having the margin excessively irregularly divided and twisted; as in many varieties of the Garden Endive, Mentha crispa, Ulmus cucullata.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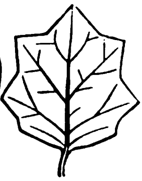
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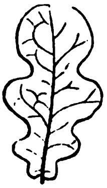
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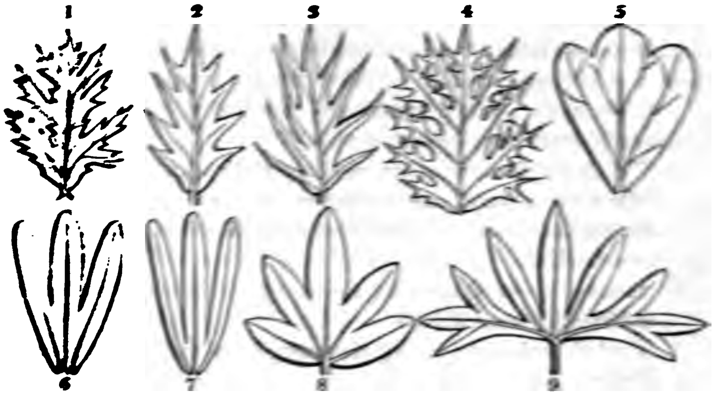
8. Repand (*repandus*, † *sinuolatus*); having an uneven slightly sinuous margin; as the leaf of Solanum nigrum.
9. Angular (*angulatus*, *angulosus*); having several salient angles on the margin; as the leaf of Datura Stramonium.
10. Sinuate (*sinuatus*); having the margin uneven, alternately with deep concavities and convexities; as the leaf of Quercus Robur.

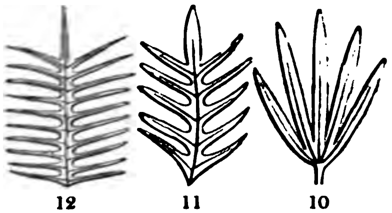
B. *With respect to Incision.*

1. Torn (*lacerus*); irregularly divided by deep incisions.
2. Cut (*incisus*); regularly divided by deep incisions.
3. Slashed (*laciniatus*); divided by deep, taper-pointed, cut incisions.
4. Squarrose-slashed (*squarroso-laciniatus*); slashed with minor divisions at right angles with the others.
5. Lobed (*lobatus*); partly divided into a determinate number of segments. We say *bilobus*, two-lobed, as in the leaf of Bauhinia porrecta; *trilobus*, three-lobed, as in the leaf of Anemone Hepatica; and so on.
6. Split (*fissus*); divided nearly to the base, into a determinate number of segments. We say *bifidus*, split in two; *trifidus*,



in three; as in the leaf of Teucrium Chamæpitys; and so on. When the segments are very numerous, *multifidus* is used.

7. Parted (*partitus*); divided into a determinate number of segments, which extend nearly to the base of the part to which they belong. We say *bipartitus*, parted in two; *tripartitus*, in three; and so on.
8. Palmate (*palmatus*); having five lobes, the midribs of which meet in a common point, so that the whole bears some resemblance to a human hand; as the leaf of Passiflora cærulea.
9. Pedate (*pedatus*); the same as palmate, except that the two lateral lobes are themselves divided into smaller segments, the midribs of which do not directly run into the same point as the rest; as the leaf of Arum Dracunculus, Helleborus niger, &c.



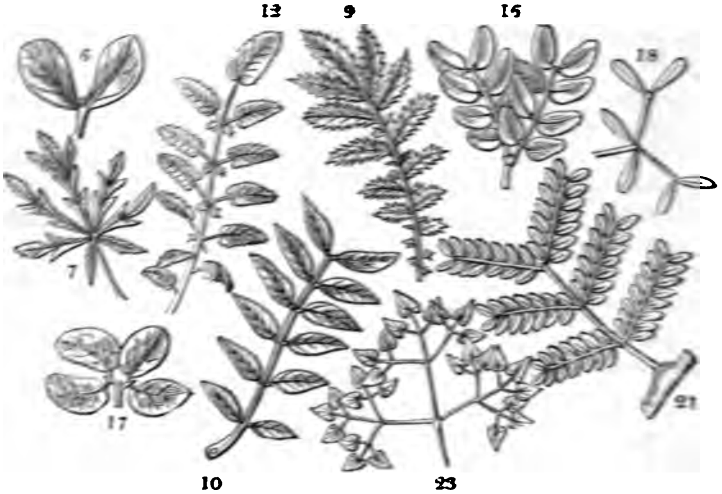
10. Fingered (*digitatus*); the same as palmate, but the segments less spreading, and narrower.
11. Pinnatifid (*pinnatifidus*, *pennatipartitus*, *pinnatiscissus*); divided almost to the axis into lateral segments, something in the way of the side divisions of a feather; as Polypodium vulgare. M. De Candolle distinguishes several modifications of pinnatifidus: — 1. *Pinnatifidus*, when the lobes are divided

down to half the breadth of the leaf: 2. *pinnatipartitus*, when the lobes pass beyond the middle, and the parenchyma is not interrupted: 3. *pinnatisectus*, when the lobes are divided down to the midrib, and the parenchyma is interrupted: 4. *pinnatilobatus*, when the lobes are divided to an uncertain depth; *lyrate* and the like belong to this modification. He has similar variations of palmatus and pedatus; viz. *palmatifidus*, *palmatipartitus*, *palmatisectus*, *palmatilobatus*; and *pedatifidus*, *pedatipartitus*, *pedatisectus*, and *pedatilobatus*.

12. Comb-shaped (*pectinatus*); the same as pinnatifid; but the segments very numerous, close, and narrow, like the teeth of a comb; as the leaf of Lavandula dentata, all Mertensias.

C. *With respect to Composition or Ramification.*

1. Simple (*simplex*); scarcely divided or branched at all.
2. Quite simple (*simplicissimus*); not divided or branched at all.
3. Compound (*compositus*); having various divisions or ramifications. As compared with the two following, it applies to cases of leaves in which the petiole is not divided; as in the Orange.
4. Decompound (*decompositus*); having various compound divisions or ramifications. In leaves it is applied to those the petiole of which bears secondary petioles; as in the leaf of Mimosa purpurea.
5. Supradecompound (*supradecompositus*); having various decompound divisions or ramifications. In leaves it is applied to such as have the primary petiole divided into secondary ones, and the secondary into a third set; as in the leaf of Daucus Carota.
6. † Bifoliolate († *bifoliolatus*, *binatus*); when in leaves the common petiole is terminated by two leaflets growing from the same point; as in Zygophyllum Fabago. This term has the same application as *unijugus* and *conjugatus*. We say *trifoliolate*, or *ternate*, when the petiole bears three leaflets from the same point; as in Menyanthes trifoliata: † *quadrifoliolate*, if there are four from the same point; as in Marsilea quadrifolia: and *quinquefoliolate*, or *quinate*, if there are five from the same point; as in Potentilla reptans: and so on.
7. † Vertebrate († *vertebratus*); when the leaf is contracted at intervals, there being an articulation at each contraction; as in Cussonia spicata. *Mirb.*



8. Pinnate (*pinnatus*); when simple leaflets are arranged on each side a common petiole; as in Polypodium vulgare.

9. Pinnate with an odd one (*impari-pinnatus*); when the petiole is terminated by a single leaflet or tendril; as in Pyrus aucuparia. If there is a tendril, as in the Pea, it is called *cirrhose*.

10. Equally pinnate (*pari-pinnatus*, *abruptè pinnatus*); when the petiole is terminated by neither leaflet nor tendril; as Orobus tuberosus.

11. † Alternately pinnate († *alternatim pinnatus*); when the leaflets are alternate upon a common petiole; as in Potentilla rupestris. *Mirb.*

12. Interruptedly pinnate (*interruptè pinnatus*); when the leaflets are alternately small and large; as in the Potato.

13. † Decreasingly pinnate († *decrescentè pinnatus*); when the leaflets diminish insensibly in size, from the base of the leaf to its apex; as in Vicia sepium. *Mirb.*

14. † Decursively pinnate († *decursivè pinnatus*); when the petiole is winged by the elongation of the base of the leaflets; as in Melianthus. *Mirb.* This is hardly different from pinnatifid.

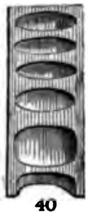
15. Digitato-pinnate (*digitato-pinnatus*); when the secondary petioles, on the sides of which the leaflets are attached, part from the summit of a common petiole. *Mirb.*

16. Twin digitato-pinnate (*bidigitato-pinnatus*, *biconjugato-pinnatus*); the secondary petioles, on the sides of which the

leaflets are arranged, proceed in twos from the summit of a common petiole; as in Mimosa purpurea. ***Mirb.***

17. Bigeminate (*bigeminatus, biconjugatus*); when each of two secondary petioles bears a pair of leaflets; as in Mimosa unguis Cati. ***Mirb.***
18. Tergeminate (*tergeminus*, † *tergeminatus*); when each of two secondary petioles bears towards its summit one pair of leaflets, and the common petiole bears a third pair at the origin of the two secondary petioles; as in Mimosa tergemina. ***Mirb.***
19. Thrice digitato-pinnate († *tridigitato-pinnatus, ternato-pinnatus*); when the secondary petioles, on the sides of which the leaflets are attached, proceed in threes from the summit of a common petiole; as in Hoffmannseggia. ***Mirb.***
20. † *Quadridigitato-pinnatus*, as in Mimosa pudica, and † *Multidigitato-pinnatus*, are rarely used, but are obvious modifications of the last.
21. Bipinnate (*bipinnatus*, † *duplicato-pinnatus*); when the leaflets of a pinnate leaf become themselves pinnate; as in Mimosa Julibrissin, Fumaria officinalis, &c.
22. Biternate (*biternatus*, † *duplicato-ternatus*); when three secondary petioles proceed from the common petiole, and each bears three leaflets; as in Fumaria bulbosa, Imperatoria Ostruthium, &c. ***Mirb.***
23. Triternate (*triternatus*); when the common petiole divides into three secondary petioles, which are each subdivided into three tertiary petioles, each of which bears three leaflets; as the leaf of Epimedium alpinum.
24. Tripinnate (*tripinnatus*); when the leaflets of a bipinnate leaf become themselves pinnate; as in Thalictrum minus, or Œnanthe Phellandrium.
25. Paired (*conjugatus, unijugus*, † *unijugatus*); when the petiole of a pinnated leaf bears one pair of leaflets; as Zygophyllum Fabago. *Bijugus* is when it bears two pairs; as in Mimosa fagifolia: *trijugus, quadrijugus, quinquejugus*, &c., are also employed when required. *Multijugus* is used when the number of pairs becomes very considerable; as in Orobus sylvaticus, Astragalus glycyphyllus.
26. Branched (*ramosus*); divided into many branches: if the divisions are small, we say *ramulosus*.
27. Somewhat branched (*subramosus*); having a slight tendency to branch.

28. Excurrent (*excurrens*); in which the axis remains always in the centre, all the other parts being regularly disposed round it; as the stem of Pinus Abies.
29. Much-branched (*ramosissimus*); branched in a great degree.
30. † Disappearing († *deliquescens*); branched, but so divided that the principal axis is lost trace of in the ramifications; as the head of an oak tree.
31. Dichotomous (*dichotomus*); having the divisions always in pairs; as the branches and inflorescence of Stellaria holostea: if they are in threes, we say *trichotomus;* as the stem of Mirabilis Jalapa.
32. Twin (*didymus*); growing in pairs, or divided into two equal parts; as the fruit of Galium.
33. Forked (*furcatus*); having long terminal lobes, like the prongs of a fork; as Ophioglossum pendulum.
34. Stellate (*stellatus*); divided into segments, radiating from a common centre; as the hairs of most malvaceous plants.
35. Jointed (*articulatus*); falling in pieces at the joints, or separating readily at the joints; as the pods of Ornithopus, the leaflets of Guilandina Bonduc: it is also applied to bodies having the appearance of being jointed; as the stem and leaves of Juncus articulatus.
36. Granular (*granulatus*); divided into little knobs or knots; as the roots of Saxifraga granulata.
37. † Byssaceous († *byssaceus*); divided into very fine pieces, like wool; as the roots of some Agarics.
38. † Tree-like († *dendroides*); divided at the top into a number of fine ramifications, so as to resemble the head of a tree; as Lycopodium dendroideum.
39. Brush-shaped († *aspergilliformis*); divided into several fine ramifications, so as to resemble the brush (*aspergillus*) used for sprinkling holy water in the ceremonies of the Catholic Church; as the stigmas of grasses.
40. Partitioned (*loculosus*, † *septatus*, † *phragmiger*); divided by internal partitions into cells; as the pith of the plant that produces the Chinese rice-paper. This is never applied to fruits.
41. Anastomosing (*anastomozans*); the ramifications of any thing which are united at the points where they come in contact are said to anastomose. The term is confined to veins.
42. Ruminate (*ruminatus*); when a hard body is pierced in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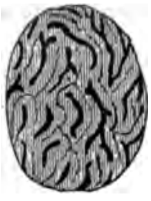
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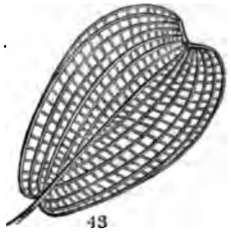
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various directions by narrow cavities filled with dry cellular matter; as the albumen of the nutmeg and the Anona.

43. † Cancellate († *cancellatus*); when the parenchyma is wholly absent, and the veins alone remain, anastomosing and forming a kind of network; as the leaves of Hydrogeton fenestralis.

44. Perforated (*pertusus*); when irregular spaces are left open in the surface of any thing, so that it is pierced with holes; as the leaves of Dracontium pertusum.

3. Of Surface.

A. *With respect to Marking or Evenness.*

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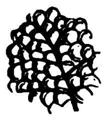

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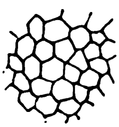

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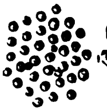

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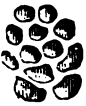

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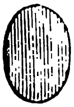

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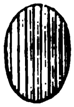

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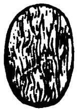

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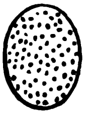
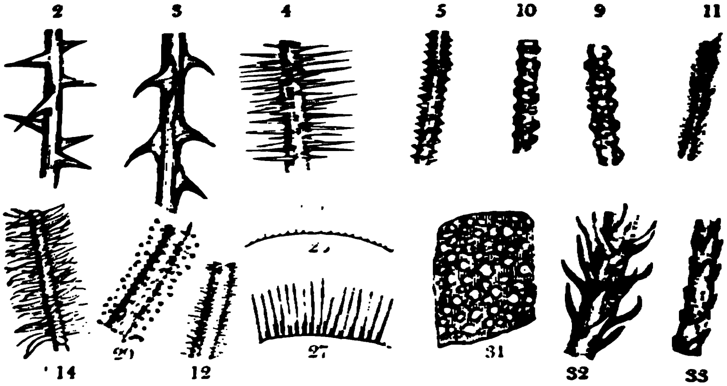


1. Rugose (*rugosus*); covered with reticulated lines, the spaces between which are convex; as the leaves of Sage.
2. Netted (*reticulatus*); covered with reticulated lines which project a little; as the under surface of the leaves of most Melastomas, the seeds of Geranium rotundifolium.
3. † Half-netted († *semireticulatus*); when, of several layers of any thing, the outer one only is reticulated; as in the roots of Gladiolus communis.
4. Pitted (*scrobiculatus*); having numerous small shallow depressions or excavations; as the seed of Datisca cannabina, Passiflora, &c.
5. Lacunose (*lacunosus*); having numerous large deep depressions or excavations.
6. Honeycombed (*favosus, alveolatus*); excavated in the manner of a section of honeycomb; as the receptacle of many Compositæ, the seeds of Papaver.

7. Areolate (*areolatus*); divided into a number of irregular squares or angular spaces.
8. Scarred (*cicatrisatus*); marked by the scars left by bodies that have fallen off: the stem, for instance, is scarred by the leaves that have fallen.
9. Ringed (*annulatus*); surrounded by elevated or depressed bands; as the roots of some plants, the cupule of several Oaks, &c.
10. Striated (*striatus*); marked by longitudinal lines; as the petals of Geranium striatum.
11. Lined (*lineatus*); the same as striatus.
12. Furrowed (*sulcatus*); marked by longitudinal channels; as the stem of Conium, of the Parsnep, of Spiræa Ulmaria, &c.
13. † Aciculated (*aciculatus*); marked with very fine irregular streaks, as if produced by the point of a needle.
14. Dotted (*punctatus*); covered by minute impressions, as if made by the point of a pin; as the seed of Anagallis arvensis, Geranium pratense.
15. Even (*æquatus*); the reverse of any thing expressive of inequality of surface.

B. *With respect to Appendages or superficial Processes.*



1. Unarmed (*inermis*); destitute of any kind of spines or prickles.
2. Spiny (*spinosus*); furnished with spines; as the branches of Cratægus Oxyacantha.
3. Prickly (*aculeatus*); furnished with prickles; as the stem of a Rose.
4. Bristly (*echinatus*); furnished with numerous rigid hairs, or straight prickles; as the fruit of Castanea vesca.

5. Muricated (*muricatus*); furnished with numerous short hard excrescences; as the fruit of the Arbutus Unedo.
6. Spiculate († *spiculatus*); covered with fine, fleshy, erect points.
7. Rough (*scaber*, *asper*, *exasperatus*); covered with hard, short, rigid points; as the leaves of Borago officinalis.
8. Roughish (*scabridus*); slightly covered with short hardish points; as the leaf of Thymus Acinos.
9. Tubercled (*tuberculatus*, *verrucosus*); covered with little excrescences or warts; as the stem of Cotyledon tuberculata, the leaf of Aloe margaritifera.
10. Pimpled (*papillosus*, † *papulosus*); covered with minute tubercles or excrescences, of uneven size, and rather soft; as the leaves of Mesembryanthemum crystallinum.
11. Hairy (*pilosus*); covered with short, weak, thin hairs; as the leaf of Prunella vulgaris, Daucus Carota.
12. Downy (*pubens*, *pubescens*); covered with very short, weak, dense hairs; as the leaves of Cynoglossum officinale, Lonicera Xylosteum, &c. Pubescens is most commonly employed in Botany, but pubens is more classical.
13. Hoary (*incanus*); covered with very short dense hairs, placed so closely as to give an appearance of whiteness to the surface from which they grow; as the leaf of Mathiola incana.
14. Shaggy (*hirtus*, *villosus*); covered with long weak hairs; as Epilobium hirsutum.
15. Tomentose (*tomentosus*); covered with dense, rather rigid, short hairs, so as to be sensibly perceptible to the touch; as Onopordum Acanthium, Lavatera arborea, &c.
16. Velvety (*velutinus*); the same as the last, but more dense so that the surface resembles that of velvet; as Cotyledon coccineus.
17. Woolly (*lanatus*); covered with long, dense, curled, and matted hairs, resembling wool; as Verbascum Thapsus, Stachys germanica.
18. Hispid (*hispidus*); covered with long rigid hairs; as the stem of Echium vulgare.
19. Floccose (*floccosus*); covered with dense hairs, which fall away in little tufts; as Verbascum floccosum, and pulverulentum.
20. Glandular (*glandulosus*); covered with hairs bearing glands upon their tips; as the fruit of Roses, the pods of Adenocarpus.

21. Bearded (*barbatus, crinitus*): having tufts of long weak hairs growing from different parts of the surface: as the leaves of Mesembryanthemum barbatum. It is also applied to bodies bearing very long weak hairs in solitary tufts or parcels: as the filaments of Anthericum, the pods of Adesmia.

22. Strigose (*strigosus*): covered with sharp, appressed, rigid hairs. *W.* Linnæus considers this word synonymous with hispid.

23. Silky (*sericeus*); covered with very fine close-pressed hairs, silky to the touch; as the leaves of Protea argentea, Alchemilla alpina, &c.

24. + Peronate (*peronatus*); laid thickly over with a woolly substance, ending in a sort of meal. *W.* This term is only applied to the stipes of Fungi.

25. Cobwebbed (*arachnoides*): covered with loose, white, entangled, thin hairs, resembling the web of a spider; as Calceolaria arachnoidea.

26. Ciliated (*ciliatus*); having fine hairs, resembling the eyelash, at the margin; as the leaves of Luzula pilosa, Erica Tetralix, &c.

27. Fringed (*fimbriatus*); having the margin bordered by long filiform processes thicker than hairs; as the petals of Cucubalus fimbriatus.

28. Feathery (*plumosus*); consisting of long hairs, which are themselves hairy; as the pappus of Leontodon Taraxacum, the beard of Stipa pennata.

29. Stinging (*urens*); covered with rigid, sharp-pointed, bristly hairs, which emit an irritating fluid when touched; as the leaves of the Urtica urens.

30. Mealy (*farinosus*); covered with a sort of white scurfy substance; as the leaves of Primula farinosa, and of some Poplars.

31. Leprous (*lepidotus, leprosus*); covered with minute peltate scales; as the foliage of Elæagnus.

32. Ramentaceous (*ramentaceus*); covered with weak, shrivelled, brown, scale-like processes; as the stems of many Ferns.

33. Scaly (*squamosus*); covered with minute scales, fixed by one end; as the young shoots of the Pine tribe.

34. Chaffy (*paleaceus*); covered with small, weak, erect, membranous scales, resembling the paleæ of Grasses; as the receptacle of many compound plants.

C. *With respect to Polish or Texture.*

1. Shining (*nitidus*); having a smooth, even, polished surface; as many leaves.
2. Smooth (*glaber*, or *lævis*); being free from asperities or hairs, or any sort of unevenness.
3. Polished (*lævigatus*, † *politus*); having the appearance of a polished substance; as the testa of Abrus precatorius, and many seeds.
4. † Glittering († *splendens*); the same as polished, but when the lustre is a little broken, from slight irregularity of surface.
5. Naked (*nudus*, *denudatus*); the reverse of hairy, downy, or any similar term: it is not materially different from glaber.
6. Opaque (*opacus*); the reverse of shining, dull.
7. Viscid (*viscidus*, *glutinosus*); covered with a glutinous exudation.
8. Mucous, or slimy (*mucosus*); covered with a slimy secretion; or with a coat that is readily soluble in water, and becomes slimy; as the fruit of Salvia Verbenaca.
9. † Greasy († *unctuosus*); having a surface which, though not actually greasy, feels so.
10. Dewy (*roridus*); covered with little transparent elevations of the parenchyma, which have the appearance of fine drops of dew.
11. † Dusty († *lentiginosus*); covered with minute dots, as if dusted; the calyx and corolla of Ardisia lentiginosa.
12. Frosted (*pruinosus*); nearly the same as roridus, but applied to surfaces in which the dewy appearance is more opaque, as if the drops were congealed; as the surface of the leaves of Rosa pruinosa and glutinosa.
13. Powdery (*pulverulentus*); covered with a fine bloom or powdery matter; as the leaves of Primula farinosa.
14. Glaucous (*glaucus*); covered with a fine bloom of the colour of a Cabbage leaf.
15. Cæsious (*cæsius*); like glaucous, but greener.
16. Whitened (*dealbatus*); covered with a very opaque white powder; as the leaves of many Cotyledons.

4. Of Texture or Substance.

1. Membranaceous (*membranaceus*); thin and semitransparent, like a fine membrane; as the leaves of Mosses.
2. Papery (*papyraceus*, *chartaceus*); having the consistence of writing-paper, and quite opaque; as most leaves.

3. Leathery (*coriaceus*, † *alutaceus*); having the consistence of leather; as the leaves of Pothos acaulis, Prunus Laurocerasus, and others.
4. Crustaceous (*crustaceus*); hard, thin, and brittle; as the testa of Asparagus, or of Passiflora.
5. Cartilaginous (*cartilagineus*); hard and tough; as the testa of an apple-seed.
6. Loose (*laxus*); of a soft cellular texture, as the pith of most plants. The name is derived from the parts of the substance appearing as if not in a state of cohesion.
7. Scarious (*scariosus*); having a thin, dry, shrivelled appearance; as the involucral leaves of many species of Centaurea.
8. Corky (*suberosus*); having the texture of the substance called cork; as the bark of Ulmus suberosa.
9. Coated (*corticatus*); harder externally than internally.
10. Spongy (*spongiosus*); having the texture of a sponge; that is to say, very cellular, with the cellules filled with air; as the coats of many seeds.
11. Horny (*corneus*); hard, and very close in texture, but capable of being cut without difficulty, the parts cut off not being brittle; as the albumen of many plants.
12. Oleaginous (*oleaginosus*); fleshy in substance, but filled with oil.
13. Bony (*osseus*); hard, and very close in texture, not cut without difficulty, the parts cut off being brittle; as the stone of a peach.
14. Fleshy (*carnosus*); firm, juicy, easily cut.
15. Waxy (*ceraceus*, *cereus*); having the texture and colour of new wax; as the pollen masses of particular kinds of Orchis.
16. Woody (*lignosus*, *ligneus*); having the texture of wood.
17. Thick (*crassus*); something more thick than usual. Leaves, for instance, are generally papery in texture; the leaves of cotyledons, which are much more fleshy, are called *thick*.
18. Succulent (*succulentus*); very cellular and juicy; as the stems of Stapelias.
19. Gelatinous (*gelatinosus*); having the texture and appearance of jelly; as Ulvas, and similar things.
20. Fibrous (*fibrosus*); containing a great proportion of loose woody fibre; as the rind of a cocoa-nut.
21. † Medullary, or pithy († *medullosus*); filled with spongy pith.

22. Mealy (*farinaceus*); having the texture of flour in a mass; as the albumen of Wheat.
23. Tartareous (*tartareus*); having a rough crumbling surface; like the thallus of some Lichens.
24. Berried (*baccatus*); having a juicy succulent texture; as the calyx of Blitum.
25. Herbaceous (*herbaceus*); thin, green, and cellular; as the tissue of membranous leaves.

5. Of Size.

Most of the terms which relate to this quality are the same as those in common use; and, being employed in precisely the same sense, do not need explanation. But there are a few which have a particular meaning attached to them, and are not much known in common language. These are, —

1. Dwarf (*nanus, pumilus, pygmæus*); small, short, dense, as compared with other species of the same genus, or family. Thus, Myosotis nana is not more than half an inch high; while the other species are much taller.
2. Very small (*pusillus, perpusillus*); the same as the last, except that a general reduction of size is understood, as well as dwarfishness.
3. Low (*humilis*); when the stature of a plant is not particularly small, but much smaller than of other kindred species. Thus, a tree twenty feet high may be *low*, if the other species of its genus are forty or fifty feet high.
4. Depressed (*depressus*); broad and dwarf, as if, instead of growing perpendicularly, the growth had taken place horizontally; as some species of Cochlearia, Coronopus Ruellii, and many others.
5. Little (*exiguus*); this is generally used in opposition to large, and means small in all parts, but well proportioned.
6. Tall (*elatus, procerus*); this is said of plants which are taller than their parts would have led one to expect.
7. Lofty (*exaltatus*); the same as the last, but in a greater degree.
8. Gigantic (*giganteus*); tall, but stout and well proportioned.

To this class must also be referred words or syllables expressing the proportion which one part bears to another.

1. *Isos*, or equal, placed before the name of an organ, indicates

that it is equal in number to that of some other understood: thus, *isostemonous* is said of plants the stamens of which are equal in number to the petals. *De Cand.*

2. *Anisos*, or unequal, is the reverse of the latter: thus, *anisostemonous* would be said of a plant the stamens of which are not equal in number to the petals.
3. † *Meios*, or less, prefixed to the name of an organ, indicates that it is something less than some other organ understood: thus, † *meiostemonous* would be said of a plant the stamens of which are fewer in number than the petals.
4. *Duplo*, *triplo*, &c., or double, triple, &c., signify that the organs to the name of which they are prefixed are twice or thrice as numerous or large as those of some other.

The terms which express measures of length are the following: —

1. A hair's breadth (*capillus*, its adjective *capillaris*); the twelfth part of a line.
2. A line (*linea*, adj. *linealis*); the twelfth part of an inch.
3. A nail (*unguis*); half an inch, or the length of the nail of the little finger.
4. An inch (*pollex*, *uncia*; adj. *pollicaris*, *uncialis*); the length of the first joint of the thumb.
5. A small span (*spithama*, adj. *spithamæus*); seven inches, or the space between the thumb and the fore-finger separated as widely as possible.
6. A palm (*palmus*, adj. *palmaris*); three inches, or the breadth of the four fingers of the hand.
7. A span (*dodrans*, adj. *dodrantalis*); nine inches, or the space between the thumb and the little finger separated as widely as possible.
8. A foot (*pes*, adj. *pedalis*); twelve inches, or the length of a tall man's foot.
9. A cubit (*cubitus*, adj. *cubitalis*): seventeen inches, or the distance between the elbow and the tip of the fingers.
10. An ell (*ulna*, *brachium*; adj. *ulnaris*, *brachialis*); twenty-four inches, or the length of the arm.
11. A toise (*orgya*, adj. *orgyalis*); six feet, or the ordinary height of man.
12. *Sesqui.* This term, prefixed to the Latin name of a measure, shows that such measure exceeds its due length by one half: thus, *sesquipedalis* means a foot and a half.

13. † A millimetre$=\frac{443}{1000}$ of a French line.
14. † A centimetre$=4$ French lines and $\frac{432}{1000}$.
15. † A decimetre$=3$ French inches, eight lines, $\frac{320}{1000}$.
16. † A metre$=3$ feet, 11 lines, $\frac{296}{1000}$ French; or, 39·371 inches English.

Obs. The last four terms are French measures, which are rarely used, and for which no equivalent Latin terms are employed.

6. Of Duration.

The terms in ordinary use to express the absolute period of duration of a plant are sufficiently precise for common purposes, but are too inaccurate to be longer admitted within the pale of science. I have, therefore, adopted the phraseology of De Candolle, as far as relates to words expressive of the actual term of vegetable existence.

1. *Monocarpous;* bearing fruit but once, and dying after fructification; as Wheat. Some live but one year, and are called annuals: the term of the existence of others is prolonged to two years; these are biennials: others live for many years before they flower, but die immediately afterwards; as the Agave americana. The latter have no English name. Annuals are indicated by the signs ⊙ or ①; biennials by ♂ or ②; and the others by ∞.
2. *Polycarpous* (better *sychnocarpous*); having the power of bearing fruit many times without perishing. Of this there are two forms: —
   - A. *Caulocarpous*, or those whose stem endures many years, constantly bearing flowers and fruits; as trees and shrubs. The sign of these is ♄.
   - B. *Rhizocarpous*, or those whose root endures many years, but whose stems perish annually; as herbaceous plants. The sign of these is ♃.
3. *Hysteranthous;* when leaves appear after flowers; as the Almond, Tussilago fragrans, &c.
4. † *Synanthous;* when flowers and leaves appear at the same time.
5. † *Proteranthous;* when the leaves appear before the flowers.
6. *Double-bearing* (*biferus*); when any thing is produced twice in one season.
7. *Often-bearing* († *multiferus*); when any thing is produced several times in one season.

Besides the foregoing, those that follow require explanation: —

1. Of an hour (*horarius*); which endures for an hour or two only; as the flowers of Talinum, Cistus, &c.
2. Of a day (*ephemerus*, † *diurnus*); which endures but a day, as the flower of Tigridia. *Biduus* is said of things that endure two days: and *triduus*, three days.
3. Of a night (*nocturnus*); which appears during the night, and perishes before morning; as the flowers of the night-blooming Cereus.
4. Of a month (*menstrualis*, † *menstruus*); which last for a month. *Bimestris* is said of things that exist for two months; *trimestris*, for three months.
5. Yearly (*annotinus*); that which has the growth of a year. Thus *rami annotini* are branches a year old.
6. Of the same year (*hornus*), is said of any thing the produce of the year. Thus *rami horni* would be branches not a year old.
7. Deciduous (*deciduus*); finally falling off; as the calyx and corolla of Cruciferæ.
8. Caducous (*caducus*); falling off very early; as the calyx of the Poppy.
9. Persistent (*persistens*, † *restans*, Linn.); not falling off, but remaining green until the part which bears it is wholly matured; as the leaves of evergreen plants, the calyx of Labiatæ and others.
10. Withering, or fading (*marcescens*); not falling off until the part which bears it is perfected, but withering long before that time; as the flowers of Orobanche.
11. Fugacious (*fugax*); falling off, or perishing very rapidly; as many minute Fungi, the petals of Cistus, &c.
12. Permanent (*perennans*); not different from persistent: it is generally applied to leaves.
13. Perennial (*perennis*); lasting for several years.

7. Of Colour.

The most useful books to consult for the distinctions of colours are Syme's *Book of Colours*, and the chromatic scale in the Duke of Bedford's publication upon Ericas.

The best practical arrangement of colours, as applied to plants, is that of Bischoff, in his excellent *Terminology;* what follows is chiefly taken from that work.

There are eight principal colours, under which all the others may be arranged; viz. white, grey, black, brown, yellow, green, blue, and red.

I. White (*albus; in words compounded of Greek, leuco-*).

1. Snow-white (*niveus*); as the purest white; Camellia japonica.
2. Pure white (*candidus; in Greek composition, argo-*); very pure, but not so clear as the last; Lilium candidum.
3. Ivory-white (cream colour; *eburneus, eborinus*); white verging to yellow, with a little lustre; Convallaria majalis.
4. Milk-white (*lacteus; in words compounded of Greek, galacto-*); dull white verging to blue.
5. Chalk-white (*cretaceus, calcareus, gypseus*); very dull white, with a little touch of grey.
6. Silvery (*argenteus*); a little changing to bluish grey, with something of a metallic lustre.
7. Whitish (*albidus*); any kind of white a little soiled.
8. Turning white (*albescens*); changing to a whitish cast from some other colour.
9. Whitened (*dealbatus*); slightly covered with white upon a darker ground.

II. Grey.

10. Ash-grey (*cinereus; in words compounded of Greek, tephro-* and *spodo-*); a mixture of pure white and pure black, so as to form an intermediate tint.
11. Ash-greyish (*cineraceus*); the same, but whiter.
12. Pearl-grey (*griseus*); pure grey, a little verging to blue.
13. Slate-grey (*schistaceus*); grey, bordering on blue.
14. Lead-coloured (*plumbeus*); the same with a little metallic lustre.
15. Smoky (*fumeus, fumosus*); grey, changing to brown.
16. Mouse-coloured (*murinus*); grey, with a touch of red.
17. Hoary (*canus*, or *incanus*); a greyish whiteness, caused by hairs overlying a green surface.
18. Rather hoary (*canescens*); a variety of the last.

III. Black.

19. Pure black (*ater; in Greek composition, mela-* or *melano-*), is black without the mixture of any other colour.

Atratus and *nigritus;* when a portion only of something is black; as the point of the glumes of Carex.

20. Black (*niger*); a little tinged with grey. A variety is *nigrescens*.
21. Coal-black (*anthracinus*); a little verging upon blue.
22. Raven-black (*coracinus*, *pullus*); black, with a strong lustre.
23. Pitch-black (*piceus*); black, changing to brown. From this can scarcely be distinguished brown black (*memnonius*).

IV. Brown.

24. Chestnut-brown (*badius*); dull brown, a little tinged with red.
25. Brown (*fuscus;* in Greek composition, *phæo-*); brown, tinged with greyish or blackish.
26. Deep-brown (*brunneus*); a pure dull brown. Umber-brown (*umbrinus*) is nearly the same.
27. Bright brown (*spadiceus*); pure and very clear brown.
28. Rusty (*ferrugineus*); light brown, with a little mixture of red.
29. Cinnamon (*cinnamomeus*); bright brown, mixed with yellow and red.
30. Red-brown (*porphyreus*); brown, mixed with red.
31. Rufous (*rufus*, *rufescens*); rather redder than the last.
32. † *Glandaceus ;* like the last, but yellower.
33. Liver-coloured (*hepaticus*); dull brown, with a little yellow.
34. Sooty (*fuligineus*, or *fuliginosus*); dirty brown, verging upon black.
35. Lurid (*luridus*); dirty brown, a little clouded.

V. Yellow.

36. Lemon-coloured (*citreus*, or *citrinus*); the purest yellow, without any brightness.
37. Golden yellow (*aureus*, *auratus ;* in Greek composition, *chryso-*); pure yellow, but duller than the last, and bright.
38. Yellow (*luteus ;* in Greek composition, *xantho-*); such yellow as gamboge.
39. Pale yellow (*flavus*, *luteolus*, *lutescens*, *flavidus*, *flavescens*); a pure but paler yellow than the preceding.
40. Sulphur-coloured (*sulphureus*); a pale lively yellow, with a mixture of white.
41. Straw-coloured (*stramineus*); dull yellow, mixed with white.

42. Leather-yellow (*alutaceus*); whitish yellow.

43. Ochre-colour (*ochraceus*); yellow, imperceptibly changing to brown.

44. *Ochroleucus;* the same, but whiter.

45. Waxy yellow (*cerinus*); dull yellow, with a soft mixture of reddish brown.

46. Yolk of egg (*vitellinus*); dull yellow, just turning to red.

47. Apricot-colour (*armeniacus*); yellow, with a perceptible mixture of red.

48. Orange-colour (*aurantiacus, aurantius*); the same, but redder.

49. Saffron-coloured (*croceus*); the same, but deeper and with a dash of brown.

50. *Helvolus;* greyish yellow, with a little brown.

51. Isabella-yellow (*gilvus*); dull yellow, with a mixture of grey and red.

52. Testaceous (*testaceus*); brownish yellow, like that of unglazed earthenware.

53. Tawny (*fulvus*); dull yellow, with a mixture of grey and brown.

54. *Cervinus;* the same, darker.

55. Livid (*lividus*); clouded with greyish, brownish, and bluish.

VI. Green.

56. Grass-green (*smaragdinus, prasinus*); clear lively green, without any mixture.

57. Green (*viridis;* in Greek composition, *chloro-*); clear green, but less bright than the last. *Virens, virescens, viridulus, viridescens,* are shades of this.

58. Verdigris-green (*æruginosus*); deep green, with a mixture of blue.

59. Sea-green (*glaucus,* † *thalassicus, glaucescens*); dull green, passing into greyish blue.

60. Deep green (*atrovirens*); green, a little verging upon black.

61. Yellowish green (*flavovirens*); much stained with yellow.

62. Olive-green (*olivaceus;* in Greek composition, *elaio-*); a mixture of green and brown.

VII. Blue.

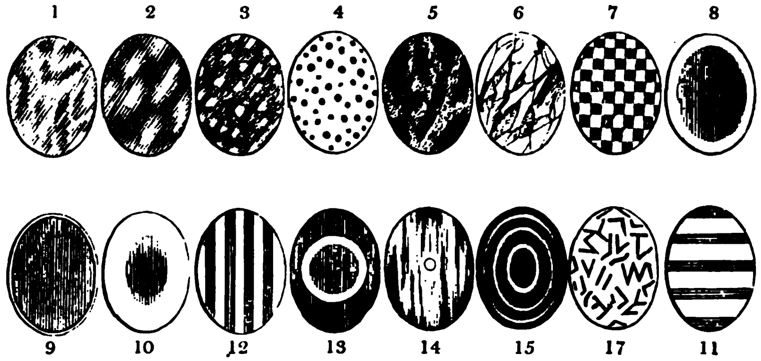
63. Prussian blue (*cyaneus;* in Greek composition, *cyano-*); a clear bright blue.

64. Indigo († *indigoticus*); the deepest blue.
65. Blue (*cæruleus*); something lighter and duller than the last.
66. Sky-blue (*azureus*); a light, pure, lively blue.
67. Lavender-colour (*cæsius*); pale blue, with a slight mixture of grey.
68. Violet (*violaceus, ianthinus*); pure blue stained with red, so as to be intermediate between the two colours.
69. Lilac (*lilacinus*); pale dull violet, mixed a little with white.

VIII. Red.

70. Carmine (*kermesinus, puniceus*); the purest red, without any admixture.
71. Red (*ruber; in Greek composition, erythro-*); the common term for any pure red. *Rubescens, rubeus, rubellus, rubicundus,* belonging to this.
72. Rosy (*roseus;* in Greek composition, *rhodo-*); pale pure red.
73. Flesh-coloured (*carneus, incarnatus*); paler than the last, with a slight mixture of red.
74. Purple (*purpureus*); dull red, with a slight dash of blue.
75. Sanguine (*sanguineus*); dull red, passing into brownish black.
76. Phœniceous (*phœniceus, puniceus*); pure lively red, with a mixture of carmine and scarlet.
77. Scarlet (*coccineus*); pure carmine, slightly tinged with yellow.
78. Flame-coloured (*flammeus, igneus*); very lively scarlet, fiery red.
79. Bright red (*rutilans, rutilus*); reddish, with a metallic lustre.
80. Cinnabar (*cinnabarinus*); scarlet, with a slight mixture of orange.
81. Vermilion (*miniatus*, † *vermiculatus*); scarlet, with a decided mixture of yellow.
82. Brick-colour (*lateritius*); the same, but dull and mixed with grey.
83. Brown-red (*rubiginosus, hæmatiticus*); dull red, with a slight mixture of brown.
84. *Xerampelinus;* dull red, with a strong mixture of brown.
85. Coppery (*cupreus*); brownish red, with a metallic lustre.
86. *Githagineus;* greenish red.

8. Of Variegation, or Marking.



1. Variegated (*variegatus*); the colour disposed in various irregular, sinuous spaces.
2. Blotched (*maculatus*); the colour disposed in broad, irregular blotches.
3. Spotted (*guttatus*); the colour disposed in small spots.
4. Dotted (*punctatus*); the colour disposed in very small round spots.
5. Clouded (*nebulosus*); when colours are unequally blended together.
6. Marbled (*marmoratus*); when a surface is traversed by irregular veins of colour; as a block of marble often is.
7. Tessellated (*tessellatus*); when the colour is arranged in small squares, so as to have some resemblance to a tessellated pavement.
8. Bordered (*limbatus*); when one colour is surrounded by an edging of another.
9. Edged (*marginatus*); when one colour is surrounded by a very narrow rim of another.
10. Discoidal (*discoidalis*); when there is a single large spot of colour in the centre of some other.
11. Banded (*fasciatus*); when there are transverse stripes of one colour crossing another.
12. Striped (*vittatus*); when there are longitudinal stripes of one colour crossing another.
13. Ocellated (*ocellatus*); when a broad spot of some colour has another spot of a different colour within it.
14. Painted (*pictus*); when colours are disposed in streaks of unequal intensity.

15. Zoned (*zonatus*); the same as ocellated, but the concentric bands more numerous.
16. Blurred (*lituratus*). This, according to De Candolle, is occasionally, but rarely, used to indicate spots or rays which seem formed by the abrasion of the surface; but I know of no instance of such a character.
17. Lettered (*grammicus*); when the spots upon a surface assume the form and appearance of letters; as some Opegraphas.

9. Of Veining.

In terms expressive of this quality the word nerves is generally used, but very incorrectly.

1. Ribbed (*nervosus*, † *nervatus*); having several ribs; as Plantago lanceolata, &c.
2. One-ribbed (*uninervis*, † *uninervatus*, *costatus*); when there is only one rib; as in most leaves.
3. Three-ribbed (*trinervis*); when there are three ribs all proceeding from the base; as in Chironia Centaurium. *Quinquenervis*, when there are five; as in Gentiana lutea. *Septemnervis*, when there are seven; as in Alisma Plantago; and so on.
4. Triple-ribbed (*triplinervis*); when of three ribs the two lateral ones emerge from the middle one a little above its base; as in Melastoma multiflora. *Quintuplinervis*, &c., are used to express the obvious modifications of this.
5. † *Indirectè venosus;* when the lateral veins are combined within the margin, and emit other little veins. *Link.*
6. † *Evanescenti-venosus;* when the lateral veins disappear within the margin. *Id.*
7. † *Combinatè venosus;* when the lateral veins unite before they reach the margin. *Id.*
8. Straight-ribbed († *rectinervis*, † *parallelinervis*, *directè venosus*, Link); when the lateral ribs are straight; as in Alnus glutinosa, Castanea vesca, &c., *Mirb.* When the ribs are straight and almost parallel, but united at the summit; as in Grasses. *De Cand.*
9. † Curve-ribbed († *curvinervis*, † *converginervis*); when the ribs describe a curve, and meet at the point; as in Plantago lanceolata.
10. † *Ruptinervis;* when a straight-ribbed leaf has its ribs interrupted at intervals. *De Cand.*

11. †*Penniformis;* when the ribs are disposed as in a pinnated leaf, but confluent at the point; as in the Date. *De Cand.*
12. †*Palmiformis;* when the ribs are arranged as in palmate leaves; as in the Chamærops. *Id.*
13. †*Penninervis;* when the ribs are pinnated (*De Cand.*); as in Castanea vesca.
14. †*Pedatinervis;* when the ribs are pedate. *De Cand.*
15. †*Palminervis;* when they are palmated. *Id.*
16. †*Peltinervis;* when they are peltate. *Id.*
17. † *Vaginervis;* when the veins are arranged without any order; as in Ficoideæ. *Id.*
18. †*Retinervis;* when the veins are reticulated, or like lace. *Id.*
19. †*Nullinervis,* or *Enervis*; when there are no ribs or veins whatever. *Id.*
20. †*Falsinervis;* when the veins have no vascular tissue, but are formed of simple, elongated, cellular tissue; as in Mosses, Fuci, &c.
21. †*Hinoideus;* when all the veins proceed from the midrib, and are parallel and undivided; as in Scitamineæ. *Link.* When they are connected by little cross veins, the term is † venuloso-hinoideus. *Id.*
22. † *Venosus;* when the lateral veins are variously divided. *Id.*

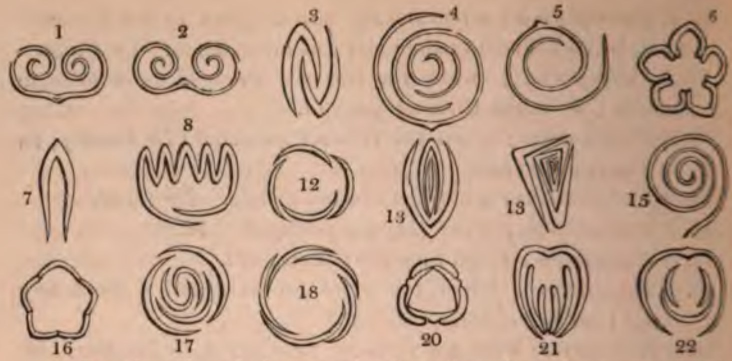
II. *Of Individual Relative Terms.*

These are arranged under the heads of *Estivation*, or the relation which organs bear to each other in the bud state; *Direction*, or the relation which organs bear to the surface of the earth, or to the stem of the plant which forms the axis, either real or imaginary, round which they are disposed; and *Insertion*, or the manner in which one part is inserted into, or adheres to, another.

1. Of Estivation.

The term *estivation*, or *præfloration*, is applied to the parts of the flower when unexpanded; and *vernation* is expressive of the foliage in the same state. The ideas of their modifications are, however, essentially the same.

1. Involute (*involutiva, involuta*); when the edges are rolled inwards spirally on each side (*Link*); as the leaf of the Apple.



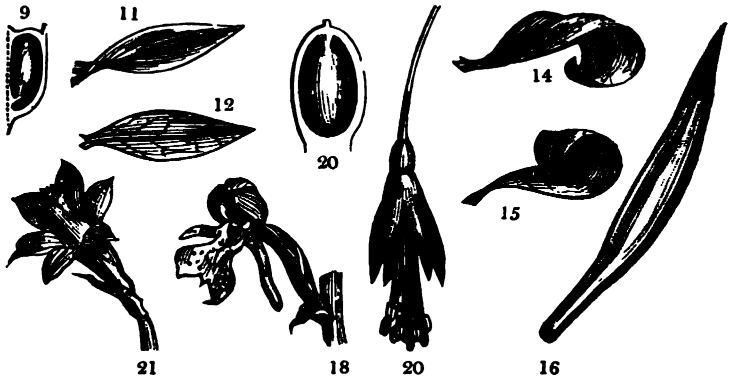
2. Revolute (*revolutiva, revoluta*); when the edges are rolled backwards spirally on each side (*Link*); as in the leaf of the Rosemary.
3. Obvolute (*obvolutiva, obvoluta,* Link; *semi-amplexa,* De Cand.); when the margins of one alternately overlap those of that which is opposite to it.
4. Convolute (*convolutiva, convoluta*); when one is wholly rolled up in another, as in the petals of the Wallflower.
5. Supervolute (*supervolutiva*); when one edge is rolled inwards, and is enveloped by the opposite edge rolled in an opposite direction; as the leaves of the Apricot.
6. Induplicate (*induplicativa*); having the margins bent abruptly inwards, and the external face of these edges applied to each other without any twisting: as in the flowers of some species of Clematis.
7. Conduplicate (*conduplicativa, conduplicata*); when the sides are applied parallelly to the faces of each other.
8. Plaited (*plicativa, plicata*); folded lengthwise, like the plaits of a closed fan; as the Vine and many Palms.
9. Replicate (*replicativa*); when the upper part is curved back and applied to the lower; as in the Aconite.
10. Curvative (*curvativa*); when the margins are slightly curved, either backwards or forwards, without any sensible twisting. *De Cand.*
11. Wrinkled (*corrugata, corrugativa*); when the parts are folded up irregularly in every direction; as the petals of the Poppy.
12. Imbricated (*imbricativa, imbricata*); when they overlap each other parallelly at the margins, without any involution. This is the true meaning of the term. M. De Candolle applies it in a different sense. (*Théorie,* ed. 1., p. 399.)

13. Equitant (*equitativa, equitans*, Link; *amplexa*, De Cand.); when they overlap each other parallelly and entirely, without any involution; as the leaves of Iris.
14. Reclinate (*reclinata*); when they are bent down upon their stalk.
15. Circinate (*circinatus*); when they are rolled spirally downwards.
16. Valvate (*valvata, valvaris*); applied to each other by the margins only; as the petals of Umbelliferæ, the valves of a capsule, &c.
17. Quincunx (*quincuncialis*); when the pieces are five in number, of which two are exterior, two interior, and the fifth covers the interior with one margin, and has its other margin covered by the exterior; as in Rosa.
18. Twisted (*torsiva, spiraliter contorta*); the same as contorted, except that there is no obliquity in the form or insertion of the pieces; as in the petals of Oxalis.
19. Contorted (*contorta*); each piece being oblique in figure, and overlapping its neighbour by one margin, its other margin being, in like manner, overlapped by that which stands next it; as Apocyneæ.
20. Alternative (*alternativa*); when, the pieces being in two rows, the inner is covered by the outer in such a way that each of the exterior rows overlaps half of two of the interior; as in Liliaceæ.
21. Vexillary (*vexillaris*); when one piece is much larger than the others, and is folded over them, they being arranged face to face; as in papilionaceous flowers.
22. Cochlear (*cochlearis*); when one piece, being larger than the others, and hollowed like a helmet or bowl, covers all the others; as in Aconitum, some species of personate plants, &c.

2. Of Direction.

1. Erect (*erectus, arrectus*); pointing towards the zenith.
2. Straight (*rectus*); not wavy or curved, or deviating from a straight direction in any way.
3. Very straight (*strictus*); the same as the last, but in excess.
4. Swimming (*natans*); floating under water; as Confervæ.
5. Floating (*fluitans*); floating upon the surface of water; as the leaves of Nuphar.

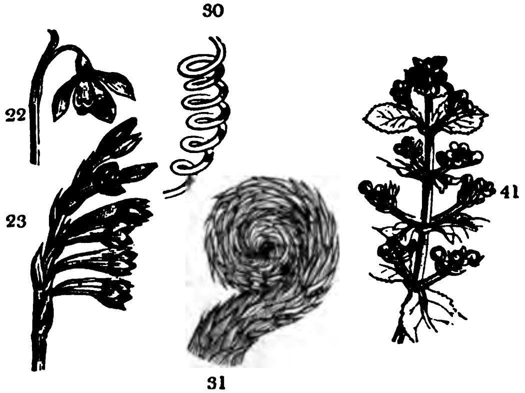
6. Submersed (*submersus, demersus*); buried beneath water.
7. Descending (*descendens*); having a direction gradually downwards.
8. Hanging down (*dependens*); having a downward direction, caused by its own weight.
9. Ascending (*ascendens, assurgens*); having a direction upwards, with an oblique base; as many seeds.



10. Perpendicular (*verticalis, perpendicularis*); being at right angles with some other body.
11. Oblique (*obliquus*); when the margin points to the heavens, the apex to the horizon; as the leaves of Protea and Fritillaria.
12. Horizontal (*horizontalis*); when the plane points to the heavens, the apex to the horizon; as most leaves.
13. Inverted (*inversus*); having the apex of one thing in an opposite direction to that of another; as many seeds.
14. Revolute (*revolutus*); rolled backwards from the direction ordinarily assumed by similar other bodies; as certain tendrils, and the ends of some leaves.
15. Involute (*involutus*); rolled inwards.
16. Convolute (*convolutus*); rolled up.
17. Reclining (*reclinatus*); falling gradually back from the perpendicular; as the branches of the Banyan tree.
18. Resupinate (*resupinatus*); inverted in position by a twisting of the stalk; as the flowers of Orchis.
19. † Inclining († *inclinatus, declinatus*); the same as reclining, but in a greater degree.
20. Pendulous (*pendulus*); hanging downwards, in consequence of the weakness of its support.

21. Drooping (*cernuus*); inclining a little from the perpendicular, so that the apex is directed towards the horizon.

22. Nodding (*nutans*); inclining very much from the perpendicular, so that the apex is directed downwards.



23. One-sided (*secundus*); having all the parts by twists in their stalks turned one way; as the flowers of Antholyza.

24. Inflexed (*inflexus, incurvus, introflexus, introcurvus, infractus*); suddenly bent inwards.

25. Reflexed (*reflexus, recurvus, retroflexus, retrocurvus, refractus*); suddenly bent backwards.

26. Deflexed (*deflexus, declinatus*); bent downwards.

27. Flexuose (*flexuosus*); having a gently bending direction, alternately inwards and outwards.

28. Tortuous (*tortuosus*); having an irregular, bending, and turning direction.

29. Knee-jointed (*geniculatus*); bent abruptly like a knee; as the stems of many Grasses.

30. Spiral (*spiralis, anfractuosus*); resembling in direction the spires of a corkscrew, or other twisted thing.

31. Circinate (*circinatus, gyratus, circinalis*); bent like the head of a crosier; as the young shoots of Ferns.

32. Twining (*volubilis*); having the property of twisting round some other body.
    a. To the right hand, or *dextrorsum;* when the twisting is from left to right, or in the direction of the sun's course; as the Hop.
    b. To the left hand (*sinistrorsum*); when the twisting is from right to left, or opposite to the sun's course; as Convolvulus sepium.

33. Turned backwards (*retrorsus*); turned in a direction opposite to that of the apex of the body to which the part turned appertains.

34. Turned inwards (*introrsus, anticus*); turned towards the axis to which it appertains.

35. Turned outwards (*extrorsus, posticus*); turned away from the axis to which it appertains.

36. Procumbent (*procumbens, humifusus*); spread over the surface of the ground.

37. Prostrate (*prostratus, pronus*); lying flat upon the earth, or any other thing.

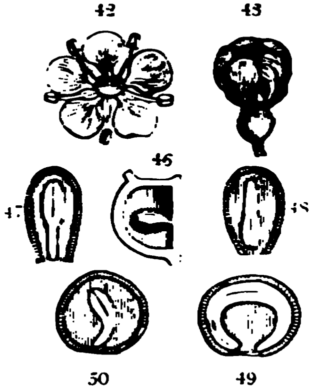
38. Decumbent (*decumbens*); reclining upon the earth, and rising again from it at the apex.

39. Diffuse (*diffusus*); spreading widely.

40. Straggling (*divaricatus*); turning off from any thing irregularly, but at almost a right angle; as the branches of many things.

41. Brachiate (*brachiatus*); when ramifications proceed from a common axis nearly at regular right angles, alternately in opposite directions.

42. Spreading (*patens*): having a gradually outward direction; as petals from the ovarium.



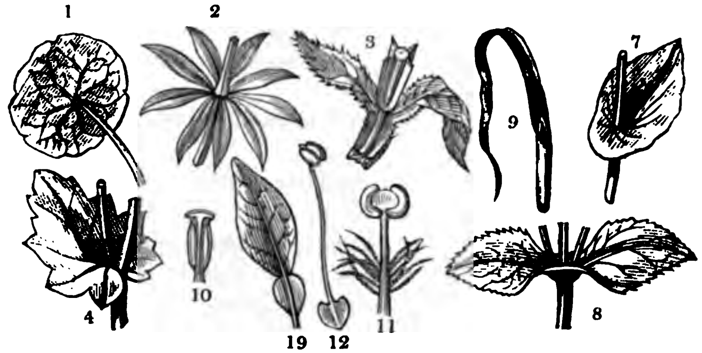
43. Converging (*connivens*); having a gradually inward direction; as many petals.

44. Opposite (*adversus*, † *oppositus*); pointing directly to a particular place; as the radicle to the hilum.

45. Uncertain (*vagus*); having no particular direction.
46. Peritropal (*peritropus*); directed from the axis to the horizon. This and the four following are only applied to the embryo of the seed.
47. Orthotropal (*orthotropus*); straight, and having the same direction as the body to which it belongs.
48. Antitropal (*antitropus*); straight, and having a direction contrary to that of the body to which it belongs.
49. Amphitropal (*amphitropus*); curved round the body to which it belongs.
50. Homotropal (*homotropus*); having the same direction as the body to which it belongs, but not being straight.

3. Of Insertion.

A. *With respect to the Mode of Attachment or of Adhesion.*



1. Peltate (*peltatus, umbilicatus*); fixed to the stalk by the centre, or by some point distinctly within the margin; as the leaf of Tropæolum.
2. Sessile (*sessilis*); sitting close upon the body that supports it, without any sensible stalk.
3. Decurrent (*decurrens, decursivus*); prolonged below the point of insertion, as if running downwards.
4. Embracing (*amplectans*); clasping with the base.
5. Stem-clasping (*amplexicaulis*); the same as the last, but applied only to stems.
6. Half-stem-clasping (*semi-amplexicaulis*); the same as the last, but in a smaller degree.

7. Perfoliate (*perfoliatus*); when the two basal lobes of an amplexicaul leaf are united together, so that the stem appears to pass through the substance of the leaf.
8. Connate (*connatus*); when the bases of two opposite leaves are united together.
9. Sheathing (*vaginans*); surrounding a stem or other body by the convolute base: this chiefly occurs in the petioles of Grasses.
10. Adnate (*adnatus, annexus*); adhering to the face of a thing.
11. Innate (*innatus*); adhering to the apex of a thing.
12. Versatile (*versatilis*, † *oscillatorius*); adhering slightly by the middle, so that the two halves are nearly equally balanced, and swing backwards and forwards.
13. Stipitate (*stipitatus*); elevated on a stalk which is neither a petiole nor a peduncle.
14. † Palaceous († *palaceus*); when the foot-stalk adheres to the margin. *Willd.*
15. Separate († *solutus, liber*, † *distinctus*); when there is no cohesion between parts.
16. Accrete (*accretus*); fastened to another body, and growing with it. *De Cand.*
17. Adhering (*adhærens*); united laterally by the whole surface with another organ. *De Cand.*
18. Cohering (*cohærens*, † *coadnatus, coadunatus*, † *coalitus*, † *connatus, confluens*); this term is used to express, in general, the fastening together of homogeneous parts. *De Cand.* Such are De Candolle's definitions of these three terms; but in practice there is no difference between them.
19. Articulated (*articulatus*); when one body is united with another by a manifest articulation.

B. *With respect to Situation.*

1. Dorsal (*dorsalis*); fixed upon the back of any thing.
2. Lateral (*lateralis*); fixed near the side of any thing.
3. Marginal (*marginalis*); fixed upon the edge of any thing.
4. Basal (*basilaris*); fixed at the base of any thing.
5. Radical (*radicalis*); arising from the root.
6. Cauline (*caulinus*); arising from the stem.
7. Rameous (*rameus, ramealis*); of or belonging to the branches.

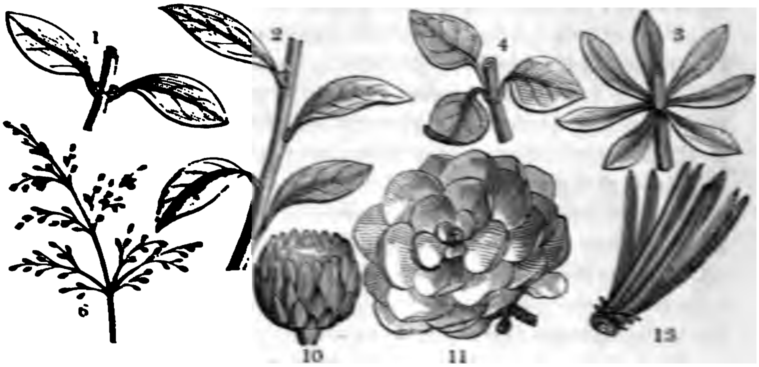
8. Axillary (*axillaris*, † *alaris*); arising out of the axilla.
9. Floral (*floralis*); of or belonging to the flower.
10. Epiphyllous (*foliaris*, *epiphyllus*); inserted upon the leaf.
11. Terminal (*terminalis*); proceeding from the end.
12. Of the leaf-stalk (*petiolaris*); inserted upon the petiole.
13. Crowning (*coronans*); situated on the top of any thing. Thus, the limbs of the calyx may crown the ovary; a gland at the apex of the filament may crown the stamen; and so on.
14. Epigeous (*epigæus*); growing close upon the earth.
15. Subterranean (*hypogæus*, † *subterraneus*); growing under the earth.
16. Amphigenous (*amphigenus*); growing all round an object.
17. Epigynous (*epigynus*); growing upon the summit of the ovarium.
18. Hypogynous (*hypogynus*); growing from below the base of the ovarium.
19. Perigynous (*perigynus*); growing upon some body that surrounds the ovarium.

Class II. Of Collective Terms.

It has been already explained, that collective terms are those which apply to plants, or their parts, considered in masses; by which is meant that they cannot be applied to any one single part or thing, without a reference to a larger number being either expressed or understood. Thus, when leaves are said to be *opposite*, that term is used with respect to several, and not to one; and when a panicle is said to be lax, or loose, it means that the flowers of a panicle are loosely arranged; and so on.

1. Of Arrangement.

1. Opposite (*oppositus*); placed on opposite sides of some other body or thing on the same plane. Thus, when leaves are opposite, they are on opposite sides of the stem; when petals are opposite, they are on opposite sides of the ovary; and so on.



2. Alternate (*alternus*): placed alternately one above the other on some common body, as leaves upon the stem.

3. Stellate (*stellatus, stelliformis, stellulatus*): the same as verticillate, No. 4., except that the parts are narrow and acute.

4. Whorled (*verticillatus*); when several things are in opposition round a common axis, as some leaves round their stem; sepals, petals, and stamens round the ovarium, &c.

5. Ternate (*ternus*): when three things are in opposition round a common axis.

6. Loose (*laxus*): when the parts are distant from each other, with an open light kind of arrangement; as the panicle among the other kinds of inflorescence.

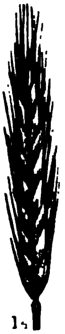
7. Scattered (*sparsus*): used in opposition to whorled, or opposite, or ternate, or other such terms.

8. Compound (*compositus*): when formed of several parts united in one common whole; as pinnated leaves, all kinds of inflorescence beyond that of the solitary flower.

9. Crowded (*confertus*): when the parts are pressed closely round about each other.

10. Imbricated (*imbricatus*): when parts lie over each other in regular order, like tiles upon the roof of a house; as the scales upon the cup of some acorns.

11. Rosulate (*rosulatus, rosularis*): when parts which are not opposite, nevertheless become apparently so by the contraction of the joints of the stem, and lie packed closely over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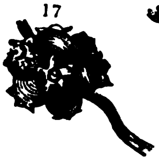
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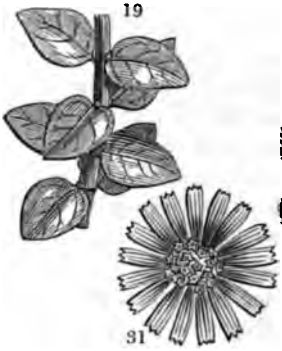
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each other, like the petals in a double rose; as in the offsets of Houseleek.

12. Cæspitose (*cæspitosus*); forming dense patches, or turfs; as the young stems of many plants.
13. Fascicled (*fasciculatus*); when several similar things proceed from a common point; as the leaves of the Larch, for example.
14. Distichous (*distichus, bifarius*); when things are arranged in two rows, the one opposite to the other; as the florets of many Grasses.
15. In rows (*serialis*); arranged in rows which are not necessarily opposite each other: *biserialis*, in two rows; *triserialis*, in three rows: but these are seldom used. In their stead, we generally add *fariam* to the end of a Latin numeral: thus, *bifariam* means in two rows; *trifariam*, in three rows; and so on.
16. One-sided (*unilateralis, secundus*); arranged on, or turned towards, one side only; as the flowers of Antholyza.
17. Clustered (*aggregatus, coacervatus, conglomeratus*); collected in parcels, each of which has a roundish figure; as the flowers of Cuscuta, Adoxa, Trientalis, &c.
18. Spiral (*spiralis*); arranged in a spiral manner round some common axis; as the flowers of Spiranthes.
19. Decussate (*decussatus*); arranged in pairs that alternately cross each other; as the leaves of many plants.
20. Fastigiate (*fastigiatus*); when all the parts are nearly parallel, with each pointing upwards to the sky; as the branches of Populus fastigiata, and many other trees.

21. Squarrose (*squarrosus*): when the parts spread out at right angles, or thereabouts, from a common axis: as the leaves of some Mosses, the involucra of some Compositæ, &c.
22. Fasciated (*fasciatus*): when several contiguous parts grow unnaturally together into one; as the stems of some plants, the fruits of others, &c.
23. Scaly (*squamosus*): covered with small scales, like leaves.
24. Starved (*depauperatus*): when some part is less perfectly developed than is usual with plants of the same family. Thus, when the lower scales of a head of a Cyperaceous plant produce no flowers, such scales are said to be starved.
25. Distant (*distans, remotus, rarus*): in contradiction to imbricated, or dense, or approximated, or any such words.
26. Interrupted (*interruptus*): when any symmetrical arrangement is destroyed by local causes, as, for example, a spike is said to be interrupted when here and there the axis is unusually elongated, and not covered with flowers; a leaf is interruptedly pinnated when some of the pinnæ are much smaller than the others, or wholly wanting: and so on.
27. Continuous, or uninterrupted (*continuus*): the reverse of the last.
28. Entangled (*intricatus*): when things are intermixed in such an irregular manner that they cannot be readily disentangled; as the hairs, roots, and branches of many plants.
29. Double, or twin (*duplicatus, geminatus*); growing in pairs.
30. Rosaceous (*rosaceus*); having the same arrangement as the petals of a single rose.
31. Radiant (*radiatus*): diverging from a common centre, like rays; as the ligulate florets of any compound flower.

2. Of Number.

1. None (*nullus*): absolutely wanting.
2. Numerous (*numerosus*): so many that they cannot be counted with accuracy: or several, but not of any definite number.
3. Solitary (*solitarius, unicus*): growing singly.
4. Many (in Greek compounds, *poly*): has the same meaning as numerous.
5. Few (in Greek compounds, *oligos*): means that the number is small, not indefinite. It is generally used in contrast with

many (*poly*) when no specific number is employed; as in the definition of things the number of which is definite, but variable

Besides the above, De Candolle has the following Table of Numbers (*Théorie*, 502.): —

Derived from the Latin.	Derived from the Greek.	Power.
uni	mono	1.
bi	di	2.
tri	tri	3.
quadri	tetra	4.
quinque	penta	5.
sex	hexa	6.
septem	hepta	7.
octo	octo	8.
novem	ennea	9.
decem	deca	10.
undecim	endeca	11.
duodecim	dodeca	12, or from 11 to 19.
viginti	icos	20.
pauci	oligos	a small number.
pluri	- -	a middling number.
multi	poly	a great number.
bini, gemini	- -	2 together.
terni, ternati	- -	3 together.
quaterni, quaternati	- -	4 together.
quini, quinati	- -	5 together.
seni	- -	6 together.
septeni	- -	7 together.
octoni	- -	8 together.
noni, noveni	- -	9 together.
deni, † denarii	- -	10 together.
duodeni	- -	12 together.
viceni	- -	20 together.
simplici	- -	solitary, or simple.
duplici	- -	double.
triplici	- -	triple.
quadruplici	- -	quadruple.
quintuplici	- -	quintuple.
sextuplici	- -	sextuple.
multiplici	- -	multiple.
tripli	- -	triple, only applied to the ribs of leaves.

Class III. OF TERMS OF QUALIFICATION.

Terms of qualification are generally syllables prefixed to words of known signification, the value of which is altered by such addition. These syllables are often Latin prepositions.

1. *Ob*, prefixed to a word, indicates inversion: thus, *ob*ovate means inversely ovate; *ob*cordate, inversely cordate; *ob*conical, inversely conical; and so on. Hence it is evident that this prefix cannot be properly applied to any terms except such as indicate that one end of a body is wider than the other; for, if both ends are alike, there can be no apparent inversion: therefore when the word *ob*lanceolate is used, as by some French writers, it literally means nothing but lanceolate; for that figure, being strictly regular, cannot be altered in figure by inversion.
2. *Sub*, prefixed to words, implies a slight modification, and may be Englished by somewhat: as, *sub*ovate means somewhat ovate; *sub*viridis, somewhat green; *sub*rotundus, somewhat round; *sub*purpureus, somewhat purple; and so on. The same effect is also given to a term by changing the termination into *ascens*, or *escens:* thus, virid*escens* signifies greenish; rub*escens*, reddish; and so on.

SIGNS.

In Botany a variety of marks, or signs, are employed to express particular qualities or properties of plants. The principal writers who have invented these signs are, Linnæus, Willdenow, De Candolle, Trattinnick, and Loudon.

* *Linn.*, *Willd.*, *De Cand.*, *Tratt.*, indicates that a good description will be found at the reference to which it is affixed.

† *Linn.*, *Willd.*, *De Cand.*, *Tratt.*, indicates that some doubt or obscurity relates to the subject to which it is affixed.

! *De Cand.*, shows that an authentic specimen has been examined from the author to whose name or work it is annexed.

? The note of interrogation varies in its effect, according to the place in which it is inserted. When found after a specific name, as *Papaver cambricum ?* it signifies that it is uncertain whether the plant so marked is that species, or some other of the genus; if after the generic name, as *Papaver ? cambricum,* it shows an uncertainty whether the plant so marked belongs to the genus Papaver; when found affixed to the name of an author, as *Papaver cambricum* Linn., Smith, Lam. ?, it signifies that, while there is no doubt of the plant being the same as one described under that name by Linnæus and Smith, it is doubtful whether it is not different from that of Lamarck. It may be remarked, that when the interrogation has a general, and not a particular, application, it should be placed at the commencement of the paragraph; as *? Papaver cambricum* Smith, &c., not *Papaver cambricum* Smith ?, &c., as is the usual practice.

♄ *Linn. Willd.* A tree or shrub.
🌳 *Loudon.* A deciduous tree.
🌲 *Loudon.* An evergreen tree.
♄ *Tratt.* A true tree; as the Oak.
♄ *De Cand.* An under-shrub; as Laurustinus.
🌱 *Loudon.* A deciduous under-shrub.
🌿 *Loudon.* An evergreen under-shrub.
♄ *De Cand.* } Caulocarpous.
♅ *Tratt.* }
♄ *De Cand.* } A shrub.
♑ *Tratt.* }
◓ *Loudon.* A deciduous shrub.
◓ *Loudon.* An evergreen shrub.
5 *De Cand.* { A small tree.
{ A tree more than twenty-five feet high.
♈ *Tratt.* } A simple-stemmed arborescent monocotyledonous tree; such as a Palm.
🌴 *Loudon.* }
♃ *Linn., Willd., De Cand., Tratt.* } A perennial.
△ *Loudon.* }
⊙ *De Cand.* Monocarpous in general.
♋ *De Cand.* } A monocarpous perennial.
○ *Tratt.* }
⊙ *Linn., Willd., Tratt.* }
① *De Cand.* } Annual.
○ *Loudon.* }
♂ *Linn., Willd.* }
② *De Cand.* } Biennial.
⊙⊙ *Tratt.* }
⚭ *Loudon.* }

♎	*Tratt.*	A plant that is propagated by new tubers, which perish as soon as they have borne a plant; as the Potato.
♀	*Tratt.*	A plant that is propagated by suckers; as Poa pratensis.
♏	*Tratt.*	A plant that is propagated by runners; as the Strawberry.
	Tratt.	A viviparous plant; or one that increases by buds which fall from it; as Lilium tigrinum.
●	*Tratt.*	A stemless plant; as Carduus acaulis.
	Tratt.	A plant whose flowers are borne upon a scape; as Hieracium Pilosella.
♓	*Tratt.*	A plant which bears its flowers and leaves upon two separate stems; as Curcuma Zedoaria. This sort of plant is called by Trattinnick *hetero-phytous*.
♍	*Tratt.*	A calamarious, or grassy, plant; as Bromus mollis.
	Loudon.	
⌒	*De Cand.*	A twining plant.
	Tratt.	
(	*De Cand.*	Which twines to the right.
)	*De Cand.*	Which twines to the left.
	Loudon.	A deciduous twining plant.
	Loudon.	An evergreen twining plant.
	Loudon.	A deciduous climbing plant.
	Loudon.	An evergreen climbing plant.
	Loudon.	A deciduous trailing plant.
	Loudon.	An evergreen trailing plant.
	Loudon.	A deciduous creeping plant.
	Loudon.	An evergreen creeping plant.
	Loudon.	A deciduous herbaceous plant.
	Loudon.	An evergreen herbaceous plant.
	Loudon.	A bulbous plant.
	Loudon.	A fusiform-rooted plant.
	Loudon.	A tuberous-rooted plant.
	Loudon.	An aquatic plant.
	Loudon.	A parasitical plant.
△	*De Cand.*, *Tratt.*	An evergreen plant.
∞	*De Cand.*	An indefinite number.
○○	*Tratt.*	
♂	*Willd.*, &c.	The male sex.
♀	*Willd.*, &c.	The female sex.
☿	*Willd.*, &c.	The hermaphrodite sex.

♄	*Willd.*	The neuter sex.
♂ — ♀ ♒	*Willd.* *Tratt.*	Monœcious; or the male and female on one plant.
♂ : ♀ ♋	*Willd.* *Tratt.*	Diœcious; or the male and female on different plants.
☿ | ♀	*Willd.*	Hermaphrodite and female in one compound flower.
☿ | ♄	*Willd.*	Hermaphrodite and neuter in one compound flower.
☿ — ♂	*Willd.*	Hermaphrodite and male on one stem.
☿ — ♀	*Willd.*	Hermaphrodite and female on one stem.

ABBREVIATIONS.

These are only known in the botanical works which are written in Latin: they are of little importance, and, as will be seen by the mark † prefixed, are scarcely ever used. The following list is chiefly taken from Trattinnick. (*Synodus*, i. 16.): —

†	Æst.	*Æstate.*
	Alb.	*Albumen.*
†	Alp.	*Alpes, Alpinus.*
	Anth.	*Anthera, Anthodium, Anthesis.*
	Apr.	*Aprilis, Apricus.*
†	Ar.	*Arena, Arenosus.*
†	Art.	*Artificialis.*
	Arv.	*Arva, Arvensis.*
†	Aug.	*Augustus.*
†	Augm.	*Augmentum.*
	Aut.	*Autumnus, Autumnalis.*
	B.	*Beatus* or *Defunctus;* used in speaking of a person who is recently deceased, and is equivalent to our English word "late."
	Br.	*Bractea.*
	Cal.	*Calyx.*
	Cald.	*Caldarium.*
†	Camp.	*Campus, Campestris.*
†	Carpell.	*Carpellum.*
†	Carpid.	*Carpidium.*
†	Carpol.	*Carpologia.*
	Cel.	*Celeberrimus.*
	Char.	*Character, Characteristicus.*

Cl.	*Clarissimus, Classis.*
† Coll.	*Collis, Collinus, Collectanea.*
Cor.	*Corolla, Corollarium.*
† Cot.	*Cotyledon.*
Cult.	*Cultus, Cultura.*
Dec.	*December, Decas, Decandria.*
Desc.	*Descriptio.*
† Des.	*Desideratur.*
Diff.	*Differentia.*
† Diss.	*Dissepimentum, Dissertatio.*
† Dum.	*Dumetum.*
Ed.	*Editio, Editor, Edulis.*
Embr.	*Embryo.*
Ess.	*Essentialis.*
† Excl.	*Exclusio.*
Fam.	*Familia.*
Feb.	*Februarius.*
Fil.	*Filamentum.*
Fl.	*Flos, Flumen, Floret, Floralis.*
Fol.	*Folium.*
Fr.	*Fructus.*
Fructif.	*Fructificatio.*
† Fun.	*Funiculus umbilicalis.*
Gen.	*Genus, Genericus.*
Germ.	*Germen.*
† Glar.	*Glareosus.*
H.	*Herbarium, Habitat.*
Hab.	*Habitat, Habeo.*
Herb.	*Herbarium, Herba.*
† Hexap.	*Hexapodium.*
Hort.	*Hortus.*
† Hortul.	*Hortulanus, Hortulanorum, Hortulus.*
† Hosp.	*Hospes, Hospitator.*
† Hum.	*Humidus, Humus.*
Ic.	*Icon*, *b.* bona, *m.* mala, *p.* picta, *l.* lignea, *n.* nigra.
Ill.	*Illustratio, Illustris.*
† Ined.	*Ineditus, Inedulis.*
Ind.	*Indicus*; *India*, *a.* australis, *or.* orientalis, *occ.* occidentalis; *Index.*
Inf.	*Inferus.*
Infl.	*Inflorescentia.*
† Inund.	*Inundatus.*

	Jan.	*Januarius.*
	Jul.	*Julius.*
	Jun.	*Junius, Junior.*
†	Juv.	*Juvenis, Juventus.*
	Lat.	*Latus, Latitudo, Lateralis.*
†	Lin.	*Linea, Linearis.*
	Lit.	*Litera.*
†	Litt.	*Littus, Littoralis.*
	L. c.	*Loco citato.*
†	Loc.	*Loculamentum, Locusta.*
	Long.	*Longus, Longitudo.*
†	Maj.	*Majus.*
†	Mar.	*Mare, Marinus.*
†	Mat.	*Matutinus, Maturus.*
	Mart.	*Martius.*
	Mont.	*Montes, Montanus.*
	Mss.	*Manuscripta.*
†	Mus.	*Museum.*
†	N.	*Numerus.*
	Nat.	*Naturalis.*
†	Nem.	*Nemus, Nemorosus.*
	No.	*Numero.*
	Nom.	*Nomen, gen.* genericum, *triv.* triviale, *s.* specificum, *barb.* barbarum, *leg.* legale, *syn.* synonymum.
	Obs.	*Observatio, Observandum.*
	Oct.	*Octobris.*
†	Or.	*Origo, Originarium, Oriens, Orientale.*
	Ord.	*Ordo, Ordinarium.*
	Ov.	*Ovarium.*
	P.	*Pagina, Pars.*
†	Pal.	*Paludes, Paludosus.*
	Ped.	*Pedunculus.*
	Peric.	*Pericarpium.*
	Perig.	*Perigonium.*
	Pet.	*Petalum, Petiolus.*
†	Phyll.	*Phyllum, Phyllodium.*
	Pist.	*Pistillum.*
	Plac.	*Placenta.*
	Poll.	*Pollen, Pollicaris.*
†	Pom.	*Pomeridianum, Pomum.*
†	Pr. v.	*Primo vere.*
	Rad.	*Radix, Radius, Radiatus.*

	Ram.	*Ramus, Rameus, Ramosus.*
†	Rec.	*Receptaculum, Recapitulatio.*
	S.	*Seu, Sive.*
†	Salt.	*Saltus, Saltuarium.*
	Sect.	*Sectio vel Divisio.*
†	Segm.	*Segmentum.*
	Sem.	*Semen, Semis.*
	Sep.	*Sepalum, Sepes.*
	Sept.	*September, Septum.*
†	Ser.	*Series.*
	Sicc.	*Siccum*
	Sp.	*Species, Specificus.*
	Spont.	*Spontaneus.*
†	Spor.	*Sporula.*
†	Sporang.	*Sporangium.*
	Stam.	*Stamen, Stamineum.*
	Stigm.	*Stigma.*
	Stip.	*Stipes, Stipula, Stipularis.*
	Styl.	*Stylus.*
	Subd.	*Subdivisio.*
	Subv.	*Subvarietas.*
	Sup.	*Superus.*
†	Sylv.	*Sylvestris, Sylva.*
	Syn.	*Synonymum, Synopsis, Synodus.*
	T.	*Tabula, Tomus.*
†	Temp.	*Tempestas, Temperatura.*
†	Tep.	*Tepidarium.*
	Trib.	*Tribus, Divisio.*
†	Triv.	*Trivialis.*
†	Turf.	*Turfosus.*
	V.	*Volumen, Vide, Vel, Vulgo.*
	Var.	*Varietas.*
	V. s. c.	*Vidi siccam cultam.*
	V. s. s.	*Vidi siccam spontaneam.*
	V. v. c.	*Vidi vivam cultam.*
	V. v. s.	*Vidi vivam spontaneam.*
	Veg.	*Vegetabile, Vegetatio.*
†	Vern.	*Vernalis, Vernaculum.*
†	Vert.	*Vertex, Verticalis.*
†	Vesc.	*Vesca, Vescarium.*
†	Vir.	*Viridarium, Vires, Viridis.*
†	Visc.	*Viscosus, Viscositas.*
†	Volv.	*Volva, Volvaceus.*

The following excellent Table of Abbreviations was contrived by the late Mr. Ferdinand Bauer, to express all the subjects for which illustrations are required in botanical drawings. It has been adopted in Endlicher's *Iconographia Generum Plantarum*, and it is to be wished that these abbreviations, which are in every way unexceptionable, should be universally adopted for references to plates: they would not only form a common means of comparison between the figures of different authors, but would also keep continually within the view of artists the nature of the subjects they are employed to analyse. It may be added that the Table, if considered without reference to the abbreviations, is in itself an excellent sketch of the principal modes, degrees, and analogies of the regular developement of fructification. When the letters used are capitals, they indicate that the object is magnified; when small, that is of the natural size; when with a score (—) drawn beneath them, that it is less than the natural size.

a.	A flower before expansion.
a 1.	A flower expanded.
b.	The operculum of a flower; generally formed by the confluence of the calyx and corolla.
c.	The perianthium; the floral integument of monocotyledonous plants, and the generally simple one of dicotyledones. (Corolla of Linnæus; calyx of Jussieu.)
c 1.	External leaflets of the perianthium; having generally the nature of a calyx. (Calyx of Linnæus.)
c 2.	Internal leaflets of the perianthium, except c 3. and c 4.; having usually the texture of petals. (Corolla of Linnæus.)
c 3.	The labellum, or its appendages. In Orchidaceæ.
c 4.	The hypogynous scales of Grasses. (Nectarium of Linnæus.)
c 5.	Appendages of the perianthium.
d.	The calyx.
e.	A monopetalous corolla.
e 1.	Petals.
e 2.	Appendages of the corolla. (Nectarium of Linnæus; parapetala of Ehrhart.)
f.	The discus, whether hypogynous or epigynous.

f 1.	Scales or glands, whether hypogynous or epigynous.
g	Sexual organs combined in a column; in Orchidaceæ and Stylidiaceæ.
g 1.	Sexual organs separate; the floral envelopes being removed.
h.	The stamens.
h 1.	An anther.
h 2.	Pollen.
h 3.	Pollen masses; in Orchidaceæ and Asclepiadaceæ.
h 4.	Sterile stamens.
h 5.	The corona of a tube of stamens; in Asclepiadaceæ. (Nectarium of Linnæus.)
i.	The pistil.
i 1.	The ovarium.
i 2.	The stigma.
i 3.	The indusium of the stigma; in Goodeniaceæ and Brunoniaceæ.
i 4.	An ovulum.
l.	A compound fruit; common to several flowers.
l 1.	Several distinct pericarpia; belonging to a single flower.
m.	Induviæ; the remains of the flower, which either increase the fruit in size, or surmount it, or are adherent to it.
m 1.	Pappus.
m 2.	The calyptra of Mosses.
n.	The pericarpium; comprehending all its species, from the simple caryopsis of Grasses.
n 1.	Pericarpium open.
n 2.	A dissepiment.
n 3.	Valves.
n 4.	An operculum.
n 5.	The peristomum of Mosses.
n 6.	The placenta. (Receptacle of the seeds of Gærtner.)
n 7.	Funiculus umbilicalis.
n 8.	The strophiola, or Caruncula umbilicalis.
n 9.	Arillus.
o.	The seed.
o 1.	Wing of the seed.
o 2.	Coma of the seed; in Asclepiadaceæ and Epilobium.
o 3.	Integument of the seed.
o 4.	Albumen. (Perisperm of Jussieu; Endosperm of Richard.)
o 5.	Vitellus; in Zingiberaceæ and Nymphæa.

p.	The embryo.
p 1.	Cotyledon.
p 2.	Plumula.
p 3.	Radicle.
q.	A leaf.
q 1.	The petiole.
q 2.	A stipula.
r.	Portion of the stem or scape.
s.	Inflorescence; comprehending all the species except the two following, s 1. and 2.
s 1.	A compound flower.
s 2.	The locusta of a Grass (either one-flowered or many-flowered.)
t.	The involucrum of an umbel, or a head.
t 1.	The involucrum of a compound flower. (Calyx communis of Linnæus.)
t 2.	Glume of Grasses. (Calyx of Linnæus.)
t 3.	Outer calyx of Malvaceæ, Dipsaceæ, Brunoniaceæ.
t 4.	Involucrum of Ferns. (Indusium of Swartz.)
t 5.	Bracteæ.
t 6.	Scales of a catkin.
t 7.	Paleæ.
t 8.	The paraphyses of Mosses.
t 9.	The calyptra when formed of connate bracteæ.
u.	Receptacle of a single flower.
u 1.	Common receptacle either of a compound flower, a catkin, or a head.
*	Placed under one of the above (thus t_{*}^{4}), shows that a part is expanded, or opened, by force.
†	Indicates a vertical section (used thus, $t_{\dagger}^{4}$).
·.·	Indicates a transverse section (used thus, $t_{\because}^{4}$).

BOOK IV.

PHYTOGRAPHY; OR, OF THE RULES TO BE OBSERVED IN DESCRIBING AND NAMING PLANTS.

I NOW proceed to investigate the principles upon which plants are described and named. It would be impossible for any person to recognise a plant which had been discovered by another, unless such a description of it were put upon record as should express all its essential features; and unless it were, at the same time, furnished with a distinctive name, it could never be subsequently spoken of intelligibly. For these reasons, the mode of describing and naming plants is one of the most important practical subjects in the science.

It may appear, at first sight, extremely easy to describe a plant, and we constantly find travellers and others attempting to do so in vulgar language; but their accounts are usually so vague, that no distinct idea can be formed of the subject of their descriptions, which remains an enigma until some botanist, following their steps, shall happen to be able to put its characters into scientific language.

The great object of descriptions in Natural History is, to enable any person to recognise a known species, after its station has been discovered in a classification; and also to put those who have not had the opportunity of examining a plant themselves into possession of all the facts necessary to acquire a just notion of its structure and affinities.

There are two means of effecting this object; the one by means of detailed descriptions, the other by the aid of briefer abstracts of the most essential characters only.

CHAPTER I.

OF DIAGNOSES; OR, OF GENERIC AND SPECIFIC CHARACTERS.

WE have seen that plants are distinguished from each other by their characters: of the application of these characters we must now speak. Were each species to be characterised independently of other species, and to be described with all the minute circumstances of structure that belong to it, the progress of investigation would be too slow, and the length of time requisite to acquire information much too great: for this reason, the process of enquiry has been simplified, by collecting in groups all those species which have certain great characters in common, and abstracting those characters, which then become the distinctions of classes: the species of a class are again collected into other groups, agreeing in some other common peculiarities, which are in like manner abstracted, and form the characters of orders. Thus reduced in extent, the species of each order are submitted to the same process of combination; the characters by which they are combined become distinctive of genera; and the species are, finally, left shorn of the greatest part of their characters, which are thus reduced within a very narrow compass. Each plant has, therefore, four characters; or, if sub-classes, sub-orders, or other modes of division are adopted, as many separate characters as there may be divisions.

These characters are of two sorts; the one called essential, the other differential. The former are the most commonly employed for orders and genera; the latter are chiefly used in discriminating species: the former are the most valuable, and will probably, in time, supersede the others, which convey little information, and are only useful in aiding us in our analysis of large bodies of species: the latter are often called definitions; but, as no definite limits can be traced between living things, a strict definition in Natural History becomes impracticable, for which reason the term differential must be admitted instead.

Differential characters express, in the least possible space, the distinctions between plants: they should contain nothing superfluous, nor any thing which can be considered implied by the contrasted characters of those with which they are to be compared. By this means the distinctions of species are brought into the least possible compass; and the analysis of their characters becomes so effectual, that a botanist is expected to be able, without difficulty, to determine the exact station and name of any one of the 100,000 species supposed to exist. Nothing can sound better than this; but, unfortunately, the advantages of differential characters are not quite so great as would appear. In sacrificing every thing to brevity, it is found in practice that doubts and ambiguities are continually created; and for this especial reason, among others, that differential characters must necessarily be framed upon a consideration of what we know, and not with reference to what we do not know: on this account, a differential character, constructed in the most unexceptionable manner by one botanist, may be unintelligible to another who possesses more knowledge, or a greater number of species. For example, when Linnæus framed the differential character of Rosa indica, "germinibus ovatis pedunculisque glabris, caule subinermi, petiolis aculeatis," it probably distinguished that species from all others that he knew: but our acquaintance with Roses is so much more extensive than that of Linnæus, that we have many Roses to which his character is equally applicable. A differential character, moreover, conveys no information beyond that of the differences between one thing and another, and can be viewed in no other light than as a convenient method of analysis. For this reason, the *essential* character is more generally adopted at the present day, either to the exclusion of the differential character, or in union with it.

The *essential* character of a plant expresses, as its name implies, those peculiarities which are known by experience to be most essential to it; but admits nothing unimportant or superfluous, or that is common to all the species of the same genus, or to all the genera of the same order, or to all the orders of the same class. It may be said to comprehend the chief differences and resemblances of bodies. In drawing up essential characters, much discretion requires to be exercised: they may be over-short or over-long; characters of importance may be omitted, and others of no importance introduced. Hence no better evidence need be desired of the merit of a botanist than his essential characters,—from which a practised eye will readily detect both how much the author knows, and what he does not know. As models of the manner in which these should be drawn up, no book can be consulted with more advantage than the *Genera Plantarum* of Jussieu, in which classical elegance of language, and as much rigid botanical precision as was supposed necessary at the time the work was written, are combined in a manner that has seldom been surpassed. The defects of that work were inseparable from the state of Botany at the time it appeared; the characters of the genera and orders not embracing all those points of structure which are now known to be essential.

The following character, assigned by Brown to the order PROTEACEÆ (*Prodr. Fl. N. Holl.* p. 363.), may be taken as a specimen of the manner in which an essential character of the briefest kind ought to be constructed:—

" *Perianthium* tetraphyllum v. quadrifidum, æstivatione valvata. *Stamina* quatuor (altero nunc sterili), foliolis perianthii opposita. *Ovarium* unicum, liberum. *Stylus* simplex. *Stigma* subindivisum. *Semen* (pericarpii varii) exalbuminosum. *Embryo* dicotyledoneus (quandoque polycotyledoneus), rectus. *Radicula* infera."

In this character enough is expressed to distinguish the order from all others; and, at the same time, by a careful suppression of all superfluous terms, it is reduced within exceedingly narrow limits. Such a character as this leaves nothing to be desired, when the essence only of a mass of characters is the object in view.

The following, from the same author, is a specimen of an essential character of ACANTHACEÆ, of a more extended kind:—

"*Calyx* 5—4-divisus, partitus v. tubulosus, æqualis v. inæqualis; rarò multifidus v. integer et obsoletus: persistens. *Corolla* monopetala, hypogyna, staminifera, plerumque irregularis; limbo ringente v. bilabiato, rarò unilabiato; nunc subæqualis; decidua. *Stamina* sæpius duo, antherifera, modo 4 didynama, brevioribus quandoque effœtis. *Antheræ* v. biloculares, loculis insertione inæqualibus æqualibusve; v. uniloculares; longitudinaliter dehiscentes. *Ovarium* disco glanduloso basi cinctum, biloculare loculis 2 polyspermis. *Stylus* 1. *Stigma* bilobum, rarò indivisum. *Capsula* bilocularis, loculis 2 polyspermis, abortione quandoque monospermis, elasticè bivalvis. *Dissepimentum* contrarium, per axin (medio quandoque apertam) bipartibile, segmentis valvulis adnatis modò ab iisdem elasticè dissilientibus, integris v. rarò spontè bipartibilibus; margine interiore seminiferis. *Semina* processubus subulatis adscendentibus dissepimenti plerumque subtensa, subrotunda: *Testa* laxa. *Albumen* nullum. *Embryo* curvatus v. rectus; *Cotyledones* magnæ, suborbiculatæ; *Radicula* teres, descendens, et simul centripeta, curvata v. recta; *Plumula* inconspicua.—— *Herbæ* v. *Frutices*, intra tropicos præcipuè provenientes; pube, dum adsit, simplici, nunc capitatâ, rarissimè stellatâ. *Folia* opposita, rarò quaterna, exstipulata, simplicia, indivisa, integra v. serrata; rarò sinuata v. sublobata. *Inflorescentia* terminalis v. axillaris, spicata, racemosa, fasciculata, paniculata v. solitaria. *Flores* in spicis sæpius oppositi, nunc alterni, tribracteati, bracteis lateralibus rarò deficientibus, quandoque magnis foliaceis calycem nanum, interdum obsoletum, includentibus."

In this instance a much greater number of particulars is introduced than in the former; but still it comprehends nothing like all the characters that would be included in a general description.

The following is also a specimen of a generic and specific character from the same author. It shows the plan upon which the essential characters of genera should be constructed: —

"VERONICA *L.*, *Juss.*

"Hebe *Juss.*

"*Calyx* 4-partitus, rarò 5-partitus. *Corolla* subrotata;

Tubus calyce brevior; *Limbus* 4-partitus, inæqualis, lobis indivisis. *Stamina* 2, antherifera, sterilia nulla. *Capsula* valvis medio septiferis v. bipartibilis. —— Herbæ *v.* Frutices. Folia *opposita, quandoque verticillata, v. alterna, sæpe dentata v. incisa.* Inflorescentia *varia.* Calyces *ebracteati.*

"§ 1. *Capsula bipartibilis.*

"1. V. *formosa,* fruticosa, foliis perennantibus decussatis lanceolatis integerrimis glaberrimis basi acutis, ramis bifariam pilosiusculis, corymbis axillaribus paucifloris." (*Prodr.* 434.)

In these characters it is difficult to say which is most to be admired, the skill with which every thing superfluous is retrenched, or the ingenuity with which every thing essential is introduced. Nothing that is general to the order is introduced into the generic character; and nothing that the generic character comprehends is discoverable in the specific. By making the peculiarity of Capsula bipartibilis the distinction of a section, the necessity of introducing that circumstance into the specific characters of any of the species comprehended in the section is avoided.

Compare with this the following generic and specific characters taken from Labillardière's *Sertum Austro-Caledonicum:* —

"Microsemma; a genus of Ternströmiaceæ (?). *Calyx* 5-phyllus, rarè 6-phyllus, persistens, foliolis tribus interioribus. *Coronula* petaloidea, petalis 10—12 distinctis. *Stamina* numerosa (30 circiter), hypogina, filamentis inter se basi subconnatis, *antheris* bilocularibus reniformibus. *Germen* globulosum, superum, *stylo* simplici, *stigmate* 5–6-fido. *Capsula* ovata, 10—12-locularis, valvis medio septiferis, 10—12-valvis. *Semina* solitaria, in summo valvularum intûs affixa, *perispermo* carnoso, *radiculâ* superâ." (p. 58.)

Upon this character it may be observed, that the calyx is described awkwardly, and at a greater expense of words than is necessary: if he had said, calyx 5–6-phyllus imbricatus, the same idea would have been expressed: rarè should be rarò. In the next place, "coronula petaloidea" is a bad term, conveying no precise notion of the organ it is intended to designate. What is a coronula? If it is a row of petals, why call it otherwise? And it appears to be so, because it is immediately afterwards described as consisting of 10—12 distinct petals. In the next sentence, hypogina is misspelt; and the anthers are said to be bilocular and reniform, a character by no means essential; while their being covered with glandular dots, and the mode of their attachment to the filament, both of which should have been introduced, are omitted. Again, the germen, meaning the ovary, is said to be globulose: what is globulose? Is it bullet-shaped, or round and small? If the former, the term is inapplicable; if the latter, the meaning is not expressed: it probably was intended for "subglobose." The capsule is said to be ovate, a quality of no consequence if it existed; but not true, inasmuch as it appears from the figure to be round. The construction of what follows is what we call in English putting the cart before the horse: instead of "valvis medio septiferis 10—12 valvis," it shonld have been, "10—12 valvis, valvis medio septiferis;" and all that is said about the attachment of the seeds might have been better expressed by two words, "semina pendula." It is said that they are attached to the top of the valves, in the inside: did any one ever hear of seeds being attached to the outside? Let the character be properly cut down, and see what remains of it.

MICROSEMMA.

"*Sepala* 5—6, imbricata, persistentia. *Petala* 10—12. *Stamina* numerosa, hypogyna, submonadelpha: *antheris* bilocularibus. *Ovarium* superum; *stylus* simplex; *stigmata* 5—6. *Capsula* 10—12-locularis, valvis totidem loculicidis; *semina* solitaria pendula; *albumen* carnosum; *radicula* supera."

But it is not in inaccuracy of language alone, or in the misplacing the members of a sentence, that an essential character may be defective: it may be expressed with a good selection of terms, and a due attention to arrangement; but the terms may be wrongly applied, or important characters may be omitted, or the author may not understand the structure of what he is describing. Take, as an instance, the following character of Carex, by the late Sir James Smith: —

" *Barren flowers* numerous, aggregate, in one, or more, oblong, dense *catkins;* their *scales* imbricated every way. *Calyx* a single, lanceolate, undivided, permanent *scale* to each floret. *Corolla* none. *Filaments* 3, rarely fewer, capillary, erect or drooping, longer than the scales. *Anthers* vertical, long, linear, of 2 cells.

" *Fertile flowers* numerous, in the same, or more usually in a different, *catkin*, very rarely on a separate plant. *Calyx* as in the barren flower. *Corolla* a single, hollow, compressed, ribbed, often angular, permanent *glume* to each floret; contracted, mostly cloven, and often elongated at the extremity. *Germen* superior, roundish; with three, rarely but two, angles, very smooth. *Style* one, terminal, cylindrical, short. *Stigmas* three, more rarely two only, awl-shaped, long, tapering, downy, deciduous. *Seed* the shape of the germen, with unequal angles, loosely coated with the enlarged, either hardened or membranous, permanent corolla, both together constituting the fruit."

This character is carefully written, but full of inaccurate and confused applications of terms. The term catkin should be spike; for a catkin is deciduous, a spike persistent: and the inflorescence in Carex is of the latter kind. In the next place, what is called the calyx is a bract. What is called the corolla of the fertile flowers is two confluent bracts; and, therefore, not a single glume, but a double one. Finally, what is called the seed is the pericarp: in the young state it is called the germen, which is equivalent to ovary; but, by the time the ovary is ripe, it is metamorphosed into a seed.

Inaccuracies of this kind not only disfigure botanical writings, but very often lead the inexperienced botanist into errors and misconceptions.

In constructing essential and differential characters, it is customary to use the nominative case for genera and orders, and the ablative for species; but in English the nominative only is employed in both cases.

CHAPTER II.

OF DESCRIPTIONS.

We have seen that the principal characters of a plant can be comprehended in the essential and differential characters. But, as these contain only such peculiarities as are supposed to be most essential, a great number of circumstances are omitted from them which, in the view of the botanist drawing them up, may appear unessential, but which to another may seem of the first importance. On this account, a plant cannot be considered completely known until a full description of every part shall have been obtained. In this description every circumstance connected with the external or internal organisation should be included, and a full statement made of all the peculiarities of every part, however obscure or difficult to observe. It is upon descriptions of this kind that systematic botany is based. Essential and differential characters are only relative to the degree of knowledge of the person who prepares them: a description is independent of all relative knowledge; it exhibits a plant as it actually is, without reference to its resemblances or differences. The former are adapted to the state of knowledge of a particular era; the latter, if complete, to that of all eras.

Notwithstanding their importance, descriptions of this kind are very rare: they occupy too much space in books to be inserted conveniently; they are difficult to draw up; and it seldom happens that an observer has the means of describing every part of a plant: the root, or the fruit, or the flower, or some other part, is probably not to be procured; and this renders a description, even in the best hands, necessarily imperfect.

In drawing up a description, care must be taken that every term is used in its strict sense; that all is perspicuous and free from ambiguity; and that the different parts are described in their just order, beginning with the root, and ending with the fruit. The following is the form in which a perfect description would be prepared: it shows the order in which the different parts are spoken of, and the points of structure to which it is desirable to advert. The student will do well to consult it carefully: he should take common plants, the descriptions of which he can find in books, and, for the sake of exercise, describe them himself according to this form; comparing them afterwards with the printed descriptions of botanists. A number of the points which I think it necessary to describe are usually overlooked by others, as unimportant, or as too difficult to ascertain: these I have marked with an asterisk; so that those points which are commonly adverted to may be distinguished from those that are usually omitted: —

Root. Its figure, quality, substance, duration, and * anatomical internal analysis.

Stem. Its figure, direction, duration, articulation, ramification, size, surface, and * internal analysis.

Leaves. Their * vernation, * internal structure, figure, articulation, insertion, margin, surface, venation, direction, colour, texture, and size.

Petiole. Its form, surface, and the proportion it bears to the leaf.

Stipulæ. Their position, texture, surface, insertion, duration, figure, and proportion to the petiole.

Inflorescence. Its nature, order of developement, ramification, position, and proportion to the leaves.

Bracteæ. Their numbers, figure, station, proportion to the adjacent parts, surface, texture, * venation.

Flowers. Their order and time of expansion.

Calyx. Its structure, figure, station with respect to the ovary and the axis of inflorescence, surface, æstivation, odour, size, proportion to the corolla, colour, and venation.

Corolla. Its structure, figure, station with respect to the ovary and axis of inflorescence and adjacent parts, surface, æstivation, size, colour, proportion to the calyx and stamens, and venation.

Stamens. Their number, direction, æstivation, station with respect to the petals, insertion, proportion to the ovarium and corolla; whether separate, or combined in several parcels; whether in one series or several, of equal or unequal length. *Filaments*, their form, length, and surface. *Anthers*, their mode of insertion on the filament; dehiscence with respect to the axis, whether inwards or outwards, and, with respect to themselves, whether transversely or longitudinally, by pores, or otherwise; their form; * structure of the endothecium; surface, colour, size; the proportion they bear to the size of the filaments, the number of their valves, the nature of the connectivum.

Pollen. Its colour, form, size, surface; whether distinct or cohering; and * mode of bursting.

Disk. If present, its size, figure, texture, and station.

Ovary. Its apparent, as well as theoretical, structure; the position of its carpels with respect to the organs around it; its surface; mode of division; number of ribs, if any; veins; cells. *Ovules*, their number; insertion upon the placenta; position with respect to the axis of the ovary; the situation of their foramen. *Styles*, their number, length, figure, surface, direction, and proportion. *Stigmas*, their number, form, and surface.

Fruit. Its texture, form; whether naked, or covered by the remains of the floral envelopes; whether sessile or stipitate; mode of dehiscence, if any; number of its valves and cells; situation of the placentæ; nature of its axis; number of its seeds.

Seed. Its position with respect to the axis of the fruit, mode of insertion, form, surface; the texture and nature of the testa, aril, and other appendages, if any; * position of the raphe and chalaza. *Albumen*, its texture, if any. *Embryo*, its direction; position with respect to the axis of the fruit, to the hilum of the seed, and to the albumen; the proportion it bears to the mass of the latter; the form of its cotyledons and radicle; * its mode of germination.

The *medical* and *economical* qualities.

Its *distribution* on the surface of the earth.

The points in which it *agrees* or disagrees with other species.

Descriptions, it must be observed, are of two kinds, collective and specific: the former explaining minutely the characters common to several species, as in an order or a genus; the latter, the character of one species only. The difference between these two, and the manner of applying each of them, will be best understood by the following examples.

The following mode of fully describing an order is taken from Adolphe Brongniart's excellent memoir on RHAMNEÆ: —

" *Calyx* monophyllus 4–5-fidus, externè sæpiùs villosus. Tubus expansus subplanus, hemisphæricus, urceolatus, campanulatus vel subcylindricus, liber, vel inferiùs ovario adnatus, vel cum eo omninò cohærens; interiùs nudus, vel in pluribus disco carnoso aut fauci limitato, aut in laciniis effuso, tectus. Laciniæ ovatæ, triangulares, rariùs subulatæ, acutæ, interiùs subcarnosæ, in pluribus in media lineâ carnosâ prominente notatæ, et apice callosæ; in præfloratione valvatìm applicatæ.

" *Petala* cum calycis laciniis alternantia, ejusque fauci inserta, sæpiùs sub margine disci affixa, unguiculata, ungue plus minùsve longo. Laminæ rariùs patentes, planæ, superiùs integræ vel emarginatæ, in plerisque concavæ, convolutæ vel cucullatæ, stamina vel eorum filamenta involventes, in pluribus nullæ. Præfloratio complicata.

" *Stamina* petalis opposita. *Filamenta* calycis fauci vel margini disci inserta, et cum unguibus petalorum basi sæpiùs cohærentia, laciniis calycis breviora. *Antheræ* in petalis cucullatis reconditæ, vel è petalis convolutis exsertæ, parte mediâ vel inferiori dorsi ad apicem filamenti affixæ, versatiles, introrsæ (rarissimè extrorsæ); vel ovatæ, biloculares, loculis parallelis, aut basi divergentibus, rimâ longitudinali dehiscentibus; vel reniformes, uniloculares (loculis superiùs confluentibus), rimâ simplici arcuatâ bivalvìm hiantes. *Pollen* siccum ellipticum, sulco secundum longitudinem notatum; madefactum sphæricum, læve, vel trimamillosum.

" *Discus* formâ maxime varians, in *Colletiâ* parvus, fundumque tubi calycis occupans; in plerisque tubum calycis strato plus minùsve crasso tegens ejusque formam accipiens (in *Zizypho*, *Paliuro*, *Ventilagine*, *Hoveniâ*, *Colubrinâ*, subplanus, pentagonus, angulis ad insertionem staminum emarginatis; in

Rhamno, Sageretiâ, Scutiâ, urceolatus vel cupulæformis), et fauci margine distincto limitatus; in aliis (*Retanillâ, Cryptandrâ, Phylicâ,* à plerisque auctoribus ut disco destitutis descriptis) super lacinias calycis etiam effusus, ejusque superficiem interiorem à fundo usque ad apicem laciniarum substantiâ carnosâ incrustans; an in quibusdam nullus? (in *Pomaderri* et *Cryptandræ* speciebus;) margine petalis staminibusque insertionem præbens.

" *Ovarium* liberum, disco plus minùsve immersum, vel calycis tubo semi-adhærens, seu omninò adhærens; ovatum vel subglobosum, bi-triloculare, rarissimè quadriloculare (in quibusdam *Rhamnis*); loculis monospermis.

" *Ovulum* in quolibet loculo solitarium erectum è fundo loculi natum, sessile vel podospermio brevi suffultum. *Podospermium,* dùm adest, ante evolutionem floris angustum, nec foramen testæ tegens, ad anthesin superiùs dilatatum, et ut cupula parva basin ovuli foramenque amplectens, celluloso-spongiosum, vasibus raphes percursum. *Testa* lævis vel dorso (in *Rhamnis*) sulco profundo notata, inferiùs prope hilum perforata. Foramen in ovulis sessilibus mammillæ albidæ endocarpii respondens, in pedicellatis cupulâ spongiosâ podospermi tectum, nec ei adhærens. Membrana testæ è stratis tribus formata, exterius cuticulatum tenuissimum, medium transversè fibrosum, testam seminis producturum, interius spongiosum, primùm maximam partem ovuli occupans, dehinc incremento nuclei evanescens, raphes vasa continens. *Membrana interior* albida, tenuis, primùm libera, deindè testæ plus minùsve adhærens (in *Pomaderri* semi-adnata, in *Phylicis, Rhamnis* aliisque pluribus omninò adnata), circum chalazam superiùs affixa, inferiùs tubulosa, perforata, tubulo in foramine testæ incluso. *Chalaza* superiùs notata, è duplici strato (ut in omnibus seminibus) formata; exteriùs vasculosa, vasorum raphes expansione producta, testæ inserta; interiùs spongiosa, in ovulo semi-evoluto fuscescens, nuclei membranâ continua. *Nucleus* subcylindricus, liber, superiùs chalazæ affixus, pendulus, inferiùs in mammillâ brevi, foramine inclusâ, productus; interiùs laxè cellulosus, in medio sacculum amnii continens, è mammillâ usque ad chalazam extensum, in cujus cavitate granula parva natant; prope mammillam embryo sub formâ globuli sphærici primùm visus est.

"*Fructus* subsphæricus, liber vel calyce adnato plùs minùsve tectus; pericarpium exteriùs carnosum, drupaceum, spongiosum vel siccum tenuissimum; interiùs (endocarpium) fibrosum, durum, plùs minùsve crassum; aut lignosum indehiscens, nucem 2-3-locularem (seu abortu unilocularem), seu nuculas 2—3 distinctas efformans; aut crustaceum dehiscens, capsulam tricoccam producens, coccis interiùs et inferiùs rimâ longitudinali dehiscentibus.

"*Semen* in quolibet loculo solitarium, erectum, sessile vel podospermio brevi cupulæformi suffultum. *Testa* lævissima, fusca, fibrosa, crustacea vel membranacea (in fructibus lignosis, ex. gr. *Zizyphis*), raphe laterali interiùs notata, vel raphe dorsali, sulco profundo exteriori inclusâ superiùsque testam perforante, prædita (in *Rhamnis*). *Chalaza*, ut in ovulo. *Nucleum* membranâ propriâ, liberâ vel testæ subadhærente, inclusum. *Endospermium* carnosum, flavescens, cellulosum, lateribus embryonis applicatum. *Embryo* magnus, semini subconformis, sed magis compressus, flavescens vel virescens, cotyledonibus planis applicatis, carnosis; radiculâ brevi inferâ.

"Arbores, frutices *vel* suffrutices, ramulis *in pluribus spinescentibus.* Folia *simplicia, alterna, subopposita, vel rariùs exactè opposita* (*in* Colletiis), *penninervia vel triplinervia, sparsa vel subdisticha, basi sæpiùs bistipulata, stipulis parvis, caducis vel spinescentibus et persistentibus* (*in* Zizyphis, Paliuro). Flores *axillares, solitarii, fasciculati, umbellati, vel cymosi, rariùs spicati, in spicis simplicibus vel interruptis* (*ramulis nudis*), *glomeratìm dispositi* (*in* Sageretiâ, Gouaniâ, Ventilagine), *in quibusdam paniculas terminales efformantes* (*in* Ceanotho, Berchemiâ, Pomaderri), *vel glomerati seu capitati* (*in* Cryptandrâ, Phylicâ, &c.)."

As an instance of a somewhat different mode of describing an order, the following natural character of AMARANTACEÆ, by the learned Dr. Von Martius, may be studied with advantage: it exhibits the manner in which characters are valued by the Botanists of Germany: —

"Flores hermaphroditi, raró diclines: dioici aut abortu polygamo-monoici, aut singuli aut nonnulli glomerati bracteati. *Perianthium* hypogynum, liberum, persistens, *duplex*, utrumque compagine simile, exterius (calyx) diphyllum, nunc deficiens (evanescens); interius (corolla) pentaphyllum, petalis distinctis aut raro connatis; rarissimè triphyllum. *Stamina* hypogyna, quina, aut quinario numero dupla aut multipla, raro pauciora, ultra quinque vix fertilia, uniserialia, nunc distincta, nunc monadelpha, in *cupulam* aut in *tubum* connata; *filamentis* fertilibus petalis oppositis; *antheris* medio dorso affixis, nunc didymis bilocularibus, nunc unilocularibus, longitudinaliter medio antice dehiscentibus, polline globoso, minuto, creberrimo. *Pistillum* unicum. *Ovarium* simplex, mono- aut oligospermum, ovulis funiculo centrali libero appensis. *Stylus* unicus vel nullus, ex ovario transiens s. continuus, et in utriculo (plerumque) persistens. *Stigma* simplex vel multiplex. *Pericarpium: Utriculus* membranaceus, evalvis et irregulariter dehiscens, aut circumscissus mono- aut oligospermus. *Semina* lentiformia, subglobosa v. elliptica, ad hilum emarginata, verticaliter appensa; testa crustacea, *membrana interna* tenui. *Albumen* centrale, farinaceum. *Embryo* periphericus, arcuatus; *cotyledonibus* plano-convexis incumbentibus; *plumula* inconspicua; *radicula* umbilicum spectante.

" *Herbæ* aut *suffrutices* ramosæ vel ramosissimæ, *caule* teretiusculo, rariùs angulato, humiles aut diffuso-incumbentes aliis vegetabilibus.

" *Folia* opposita vel alterna, simplicia, sæpè brevitèr petiolata, integra, subintegerrima uninervia, venis subparallelis combinatis, venulis creberrimè reticulatis, exstipulata.

" *Flores* pedicellis brevissimis subsessiles, sicciusculi, scariosi et quasi glumacei, glomerati, capitati vel spicati, colore vario. *Pubes* frequens, septata, articulata aut ganglionea, plerumque simplex, raro stellata.

" *Evolutio.*

" *Cotyledones* epigææ, integerrimæ, glaberrimæ, subsuccosæ, in alternifoliis nonnunquam obliquè oppositæ, in oppositifoliis basi conjugatæ. *Radicula* subsimplex, fibrillosa, et *Cauliculus* crassiusculi, internodio primario sæpè elongato. *Folia plumulæ* vernatione sursum complicata. *Gemmatio:*

Gemmis nudis. *Æstivatio calycina* equitans. *Æstivatio corollina* interdum apice aperta (dum corolla calyce inclusa), quincuncialis: duobus tribusve petalis exterioribus, sibi lateraliter imbricatis et interiores subvalvulares, vel hinc imbricatas plus minusve tegentibus.

" *Æstivatio staminea* erecta, pistillo ante anthesin sæpè stamina superante, postea incluso. *Prolepsis* florum composita et indeterminata (*Link*). *Anthesis* sursum peracta.

" *Propagatio.*

" *Antherarum* dehiscentia simultanea, completa, antheris effœtis explanatis vel tortis et versatilibus. *Stigma* pollen papillis pilisque affigens, dum divisum sensim sensimque expansum. *Disseminatio* aut floribus integris super pericarpium semenque clausis decidentibus, sæpè ope lanæ involventis volitantibus, seminibusve aut ex utriculo circumscisso libere aut una cum utriculo delabentibus.

" *Metamorphosis.*

" Folia sursum magnitudine decrescentia, floralia nunc reliquis minora, nunc omnino deficientia aut in squamas ad divisiones florescentiæ mutata, bractearum sub specie contracta, sicca, scariosa atque calycis foliolis similia. Foliolorum calycinorum fabrica et species quasi repetita in petalis vix in orbem regularem dispositis, orbe non nisi in staminum monadelphorum perigynia absoluto.

" *Metamorphosis retrocedens* s. *negativa* in florum glomerulis, nonnullos flores in gemmulas spinosas coërcens.

" *Luxuries* caules rachesque florum fasciatos vel florum diclinorum hermaphroditismum incompletum sistens, aut semina in corpuscula vacua caudata extenuans.

" *Qualitas.*

" Herbæ, præsertim junioris, *folia* textura laxiuscula molli, elementis mucilaginosis, saccharinis et fibrosis pollentia ideoque oleracea. *Semina* farinacea, amylo et muco pollentia. Virtus nutriens, emolliens, demulcens, in systema lymphaticum prævalens. Unicæ hucusque speciei cognitæ, *Gomphrenæ officinalis* Mart., radix antidotalis, tonica, stimulans.

"*Statio et Habitatio.*

"Plantæ et gregariæ et solitariæ; plures diffusæ villosiores in siccis lapidosis arenosisve apricis regionibus, aliæ erectæ vel super alia vegetabilia decumbentes, pube rariore adspersæ, in sylvarum marginibus lucisque primævis vivunt: nonnullæ subsalsa maritimaque diligunt loca; in depressis, haud multum super oceanum elevatis, frequentiores ac in montanis. Obviam venit hæc plantarum familia in utroque hemisphærio; sub ipsa Æquatore rariùs, inde si versus Polos procedas, utrinque frequentior, ita ut ejus vis versus Tropicas augeri videatur. Cujusvis generis *Plaga* ampla, aliis Americæ, Asiæ, Novæ Hollandiæ peculiaribus, aliis paucissimis communibus, paucis hucusque Europæis et Africanis."

As an example of a full description of a species, the following account of Cephaelis Ipecacuanha is taken from Von Martius's *Materia Medica Brasiliensium*: —

"*Radix* perennis, simplex vel in ramos paucos divergentes divisa, oblique terram intrans, flexuosa, torta, 4—6 pollices longa, raró longior, pennam anserinam circiter crassa, versus basin et apicem plerumque paulo attenuata, annulata, annulis ut plurimum ultra dimidiam radicis crassitiem latis inæqualibus; passim fibras agens tenues, flexuosas, simplices vel parum divisas in fibrillas patentes; *epidermide* lævigata, glabra, in planta viva dilute fusca, in sicca umbrina et tandem umbrino-nigricante vel griseo-fusca obductas; cortice seu parenchymate, quod annulos exhibet, æquabili, primum molliusculo, subamylaceo, albo, tandem siccescente pallide rubente vel testaceo-roseo, resinoso-splendente, facilius a filo centrali lignoso tereti dilute flavido secedente, idque passim in conspectum dante.

"*Caulis* suffruticosus, 2—3 pedes longus, adscendens, interdum declinatus inque terra latitans, passim nodosus et e nodis radices agens reliquis similes, ut plurimum simplices, teres, crassitie pennæ anserinæ vel cygneæ, vel simplicissimus, vel adultior ramos paucos sarmentoso-emittens; *epidermide* crassiuscula lævigata vel longitudinaliter rimis aperta, in parte subterranea fusca, in parte extraterranea inferiore foliis destituta cinereo-alba glabra, in superiore viridi pubescente.

" *Folia* in apice caulis ramorumque 4—6, rarò plura, opposita, subhorizontaliter patentia, petiolata, oblongo-obovata, acuta, versus basin attenuata, margine integerrima vel obiter subrepanda, 3—4 pollices longa, 1—2 lata, uti pars suprema caulis et ramorum pilis brevibus adpressis scabriuscula, obscurè viridia, subtùs pallida, nervo medio venisque lateralibus ibidem prominentibus percursa.

" *Petioli* semiunguiculares, semiteretes, supra paulò canaliculati, pubescentes.

" *Stipulæ* petiolos connectentes, erectæ, adpressæ, basi membranaceæ supernè utrinque in lacinias setosas 4—6 fissæ, marcescentes et cum foliis deciduæ.

" *Pedunculi* solitarii, axillares, teretes, pubescentes, floriferi erectiusculi, fructiferi refracti, unciam et ultra longi.

" *Flores* in capitulum involucratum semiglobosum collecti, 8—12, rarò plures, in quovis involucro, singuli bracteati.

" *Involucrum commune* monophyllum, patens, profunde 4-rarius 5—6-partitum, in lacinias obovatas brevi acumine terminatas ciliatas.

" *Bracteæ* (s. *involucrum partiale*) pro singulo flore singulæ, ovato-oblongæ, acutæ, pubescentes.

" *Calyx* ovario adnatus, minutus, obovatus, albidus, extùs pubescens, supernè sectus in dentes 5 breves obtusiusculos erectos.

" *Corolla* alba, infundibuliformis, tubo cylindrico vix sursum dilatato, extùs et in fauce tenuissimè pubescens, limbo quam tubus duplo breviore, in lacinias 5 ovatas acutiusculas patenti-reflexas diviso.

" *Stamina* 5. *Filamenta* filiformia, alba, glabra, in tubi parte superiore adnata. *Antheræ* lineares, quam filamenta paulò longiores, nonnihil exsertæ.

" *Ovarium* calyce inclusum, obovatum, in vertice disco carnoso medio umbilicato albido notatum. *Stylus* filiformis, longitudine tubi corollini, albus. *Stigmata* 2, linearia, obtusa, patentia.

" *Bacca* ovata, obtusa, magnitudine vix semen *Phaseoli multiflori* æquans, primum purpurea, dein violaceo-atra, carnosa, mollis, calyce parvo non ampliato coronata, bilocularis, dissepimento longitudinali carnoso, disperma.

"*Nuculæ* 2, hinc convexæ inde planæ ibidemque sulco tenui exaratæ, pallidæ, testaceæ, glabræ. *Nucleus* albus, albumine corneo, embryone erecto subclavato."

A briefer and comparative mode of describing species is, however, more frequently employed; of which the following of Hypericum perforatum, from Sir James Smith's *English Flora*, is a good instance: —

"*Root* woody, somewhat creeping. *Stem* taller than the last (H. quadrangulum), and much more bushy, in consequence of the much greater length of its axillary leafy branches: its form round, with only two opposite ribs or angles, not so acute as those of *H. quadrangulum*. The whole herb is moreover of a darker green, with a more powerful scent when rubbed; staining the fingers with dark purple, from the greater quantity of coloured essential oil lodged in the herbage and even in the *petals*. *Leaves* very numerous, smaller than the last; elliptical, or ovate, obtuse, various in width. *Flowers* bright yellow, dotted and streaked with black or dark purple; numerous, in dense, forked, terminal panicles. *Calyx* narrow. *Styles* short, erect. *Capsule* large, ovate." (*English Flora*, iii. 325.)

In order to show the materials from which a plant is described, it has become customary to add immediately after the indication of its native country, within a parenthesis, certain explanatory abbreviations; such as v. s. sp. (vidi siccam spontaneam), meaning that a wild specimen has been examined in a dried state; or v. s. c. (vidi siccam cultam), meaning that a cultivated specimen has been examined in a dried state; v. v. sp. (vidi vivam spontaneam), meaning that it has been seen wild in a living state; or v. v. c. (vidi vivam cultam), meaning that it has been seen cultivated in a living state; and the like. These are useful things to know, because it enables a reader to judge of the goodness of the materials from which an author has been describing. But they are capable of much improvement. It now appears, indeed, whether a plant has been seen alive or dried, wild or cultivated, but we have nothing to show what the nature of the examination has been to which it has been subjected in either. A plant may have been seen alive, and not examined or analysed until it was dried; another may have been inspected in a dried state, without having been analysed; or, if analysed, the analysis may have been very imperfect: no examination may have been made of the interior of the ovary, of the fruit, or of the seed; all points upon which it is useful to possess information. It is, therefore, desirable that some alteration, or rather extension, of these abbreviations should be contrived, something after the following manner:—*v. v. et ex. fl. ov. fr. s.*; "seen alive and examined, flower, ovarium, fruit, and seed:" if all these are named, they will all have been examined; if part only, then the other parts will be understood not to have been examined. The great necessity of making some such addition as this will, I am sure, be felt by every one accustomed to consult botanical works. At all events, it is indispensable that it should be stated whether a plant has been examined sufficiently, as well as seen; because merely to inspect a plant in a herbarium will often enable the observer to form but a very imperfect idea of its organisation. For this reason I have introduced the abbreviation *exam.* (examinavi) into some of my own works, thus: —

"Habitat in *Mexico; Pavon.* (*exam. s. sp. in Herb. Lambert.*)"

Connected with this subject is the mode of stating the native countries of plants, and of citing the authorities upon which the statement is made. For this purpose the two rules of De Candolle are unexceptionable.

1. If you have yourself seen a specimen collected in its native country, then the name of the collector, which is placed immediately after that of the country, is printed in italics: but, 2. If you have no other authority for the habitation than some printed book or manuscripts, then the name of the author from whom you derive your information is printed in Roman characters; thus: —

"Hab. in Mexico, *Graham;* Caribæis, Jacquin; Florida, *Frazer;* Louisiana, Rafinesque."

Here it is seen that you have examined Mexican specimens collected by Mr. Graham, and Florida ones from Frazer; but that you trust to the writings of Jacquin and Rafinesque for its being also found in the West Indies and in Louisiana.

CHAPTER III.

OF PUNCTUATION.

As the principle of composing and punctuating generic and specific characters and descriptions, when written in Latin, differs from that employed in ordinary composition, a few rules upon the subject may with propriety be introduced here.

In the *characters of classes*, *orders*, or *genera*, the nominative case is employed, the ablative being only occasionally introduced: each adjective is separated by a comma; and the different members of a character by a semicolon, or a period; as: "*Perianthium* deciduum. *Ovarium* liberum, sessile, monospermum, ovulo erecto. *Stylus* brevissimus. *Stigma* sublobatum. *Semen* nucamentaceum, arillo multipartito. *Albumen* ruminatum, sebaceo-carnosum."

Or, —

"*Perianthium* deciduum. *Ovarium* liberum, sessile, monospermum, ovulo erecto; *stylus* brevissimus; *stigma* sublobatum. *Semen* nucamentaceum, arillo multipartito; *albumen* ruminatum, sebaceo-carnosum."

The latter is the better of the two, because the semicolons show that the parts connected by them all form portions of the same organ; while, if the period is exclusively used, it would appear as if the parts divided by it were all so many distinct organs.

In *specific characters*, it is customary to employ the ablative case; not to separate the adjectives that belong to the same noun by any point; to use commas to divide the members of the sentence; to employ the colon to indicate when a new sentence forms a part of that which precedes; and to exclude the semicolon altogether, or to employ it to separate adjectives in the nominative case, when such are introduced, as is sometimes the case, from the ablative part of the character. Thus we write, —

" Stemodia *balsamea*, caule procumbente, ramis subhirsutis, foliis ovatis obtusis basi in petiolum brevem angustatis glabris: floralibus conformibus, floribus axillaribus sessilibus solitariis vel utrinque 2—3-glomeratis, calycibus 5-partitis: laciniis lanceolato-subulatis."

And not, —

" Stemodia *balsamea*, caule procumbente, ramis subhirsutis, foliis ovatis, obtusis, basi in petiolum brevem angustatis, glabris, floralibus conformibus, floribus axillaribus, sessilibus, solitariis, vel utrinque 2—3-glomeratis, calycibus 5-partitis, laciniis lanceolato-subulatis."

If this character were punctuated in the latter manner, it would not be certain whether or not laciniis referred to calyx, or to any thing else; in the former case it is distinctly indicated.

If a semicolon is introduced into a specific character, it is when an adjective in the nominative case immediately follows the specific name, preceding all that part that is in the ablative: thus, —

" Gesneria *misera*, procumbens; foliis obovatis villosis," &c.

In *detailed descriptions*, the mode of composing and punctuating is much the same as in the characters of genera; the nominative case being chiefly used, and commas being placed between each adjective. The members of a sentence are divided by semicolons; and if colons are employed, it is in the same sense as in specific characters.

Although such are the most approved rules of punctuation, yet it must be confessed they are little attended to by many Botanists; although it cannot be doubted that they tend very much to perspicuity and precision of language.

CHAPTER IV.

OF NOMENCLATURE AND TERMINOLOGY.

The following are the canons instituted by Linnæus, with reference to this subject. They are what guide the Botanist in his doubts; and, although exceptionable in some points, as will hereafter appear, are, upon the whole, well deserving of attention and respect.

1. The names of plants are of two kinds; those of the class and order, which are *understood;* and of the genus and species, which are *expressed.* The name of the class and order never enter into the denominations of a plant.

2. All plants agreeing in genus are to have the same generic name.

3. All plants differing in genus are to have a distinct generic name.

4. Each generic name must be single.

5. Two different genera cannot be designated by the same name.

6. It is the business of those who distinguish new genera to name them.

7. Generic names derived from barbarous languages ought on no account to be admitted.

8. Generic names compounded of two entire words are improper, and ought to be excluded. Thus, Vitis Idæa must give way to Vaccinium, and Crista Galli to Rhinanthus.

9. Generic names formed of two Latin words are scarcely tolerable. Some of them have been admitted, such as Cornu*copiæ*, Ros*marinus*, Semper*vivum*, &c., but these examples are not to be imitated.

10. Generic names formed half of Latin and half of Greek are hybrid, and on no account to be admitted: such are Cardam*indum*, Chrysanthem*indum*, &c.

11. Generic names compounded of the entire generic name of one plant, and a portion of that of another, are unworthy of Botany; such as Cann*acorus*, Lilio*narcissus*, Lauro-*cerasus*.

12. A generic name, to which is prefixed one or more syllables, so as to alter its signification, and render it applicable to other plants, is not admissible. *Bulbo*castanum, *Cyno*crambe, *Chamæ*nerium, &c., are of this kind.

13. Generic names ending in *oides* are to be rejected; as, Agrimon*oides*, Aster*oides*, &c.

14. Generic names formed of other generic names, with the addition of some final syllable, are disagreeable, as Aceto*sella*, Balsam*ita*, Rap*istrum*, &c.

15. Generic names sounding alike, lead to confusion.

16. No generic names can be admitted, except such as are derived from either the Greek or Latin languages.

17. Generic names appertaining previously to Zoology, or other sciences, are to be cancelled, if subsequently applied in Botany.

18. Generic names at variance with the characters of any of the species are bad.

19. Generic names the same as those of the class or order cannot be tolerated.

20. Adjective generic names are not so good as substantive ones, but may be admitted.

21. Generic names ought not to be misapplied to gaining the goodwill or favour of saints, or persons celebrated in other sciences; they are the only reward that the Botanist can expect, and are intended for him alone.

22. Nevertheless, ancient poetical names of deities, or of great promoters of the science, are worthy of being retained.

23. Generic names that express the essential character or habit of a plant are the best of all.

24. The ancient names of the classics are to be respected.

25. We have no right to alter an ancient generic name to one more modern, even although it may be for the better: this would, in the first place, be an endless labour; and, in the next place, would tend to inextricable confusion.

26. If new generic names are wanted, it must be first ascertained whether no one among the existing synonymes is applicable.

27. If an old genus is divided into several new ones, the old name will remain with the species that is best known.

28. The termination and euphony of generic names are to be consulted, as far as practicable.

29. Long, awkward, disagreeable names are to be avoided, such as Calophyllodendron of Vaillant, Coriotragematodendros of Plukenet, and the like.

30. The names of classes and orders are subject to the same rules as those of genera. They ought always to express some essential and characteristic marks.

31. The names of both classes and orders must always consist of a single word, and not of sentences.

I have thought it right to give these Linnæan canons, firstly, because they are undoubtedly excellent in many respects; secondly, because we must attribute much of the greater perfection of natural history, since the time of Linnæus, to the adoption of them; and, thirdly, because they are constantly appealed to, by the school of Linnæus, as a standard of language, from which no departure whatever is allowable.

It is, however, necessary to remark, that, notwithstanding the undoubted excellence of many of these rules, yet there are others adherence to which is often out of the question, and which have, indeed, fallen wholly into disuse. It seems to be an admitted principle, that it is of little real importance what name an object bears, provided it serves to distinguish that object from every thing else. This is the material point, to which all other considerations are secondary: thus, if A. or B. are universally known by the names of Thomas or John, it is quite as well as if they were called William or James. This being so, it will follow that Nos. 7, 9, 11, 12, 14, and 16, of the Linnæan canons, are either frivolous or unimportant; or, at least, that no person is bound, either in reason or by custom, to observe them. This is particularly apparent in considering the practice now universally adopted, although condemned by Linnæus, of converting the names by which plants are known in countries called barbarous, into scientific generic names, by adding a Latin termination to them. The advantage of this practice to travellers is known to be very great, as it puts them in possession of a certain part of the language of the country in which the plants are found. Such names are often not less euphonous than those admitted by the Linnæan school as unexceptionable: witness, Licaria and Eperua, rejected Caribean generic names; and Glossarrhena, Guldenstadtia, Schlechtendahlia; and similar admitted Linnæan names. Indeed, so impossible is it to construct generic names that will express the peculiarities of the species they represent, that I agree with those who think a good, well-sounding, *unmeaning* name as good as any that can be contrived. The great rule to follow is this: —

In *constructing* a generic name, take care that it is harmonious, and as unlike all other generic names as it can be. In *adopting* a generic name, always take the most ancient, whether better or worse than those that have succeeded it. Attend as much as you will to the canons of Linnæus in forming a name of your own; but never allow them to induce you to commit the incivility of rejecting the names of other persons, because they do not think fit to acknowledge arbitrary rules which you are disposed to obey; and let the conduct of Schreber, a German Botanist, who has been held up to universal scorn for having presumed, without authority, or any sort of pretension to a knowledge of the plants of Aublet, to alter the whole nomenclature of that author, to the great confusion of science, be a warning to you, never to be induced to sanction any similar deviation from the rules of courtesy in science.

When species are named after individuals, the rule of construction is this: if the individual is the discoverer of the plant, or the describer of it, the specific name is then to be in the genitive singular; as Caprifolium Douglasii, Carex Menziesii; Messrs. Douglas and Menzies having been the discoverers of these species; and Planera Richardi, the species so called having been described by Richard: but if the name is merely given in compliment, without reference to either of these circumstances, the name should be rendered in an adjective form, with the termination *anus, a, um;* as Pinus Lambertiana, in compliment to Mr. Lambert: and, for this reason, such names as Rosa Banksiæ and R. Brunonii are wrong; they should have been R. Banksiana and R. Brunoniana.

It is customary to name an order from the genus that most accurately represents its characters, altering into *aceæ* the termination of such names as end in *a* or *as*, or even *us;* as Rosaceæ from Rosa, Spondiaceæ from Spondias, Connaraceæ from Connarus: or by converting the terminations *us* or *um* into *eæ;* as Rhamneæ from Rhamnus, Menispermeæ, from Menispermum. But this is not very strictly adhered to; many well-known old names, not constructed upon this principle, being still retained; such as Salicariæ, Leguminosæ, Caryophylleæ, Gramineæ, Palmæ, &c.

There is no rule for the construction of the names of the higher divisions in Botany.

In terminology, every name should have a distinct positive meaning, which cannot be misunderstood; all terms that have two meanings being bad. For instance, the term nectary, which is sometimes applied to glands secreting honey, sometimes to modifications of the petals or stamens, and even to the disk itself, is, in such an extended signification, unintelligible. Again, the term corolla, unless limited to the inner series of the floral envelopes, may be often applied to the calyx, and then ceases to have any precise signification. Capsule has been applied by various authors to a polyspermous dehiscent compound fruit, or to an indehiscent polyspermous fruit, or to an indehiscent monospermous fruit: so applied it has no distinct meaning. For this reason modern botanists have contrived a large number of new terms, which have contributed much to the perspicuity of botanical writings. But, if this has been, in many cases, done advantageously, it has unfortunately happened that in others additional terms have been created uselessly, to the great confusion of the science. Thus, the old word albumen is perfectly well understood as the matter lying between the embryo and the seed coats when the seed is mature; nevertheless, we have the terms perisperm and endosperm contrived for the same part: testa is synonymous with episperm; putamen with endocarp: for funiculus umbilicalis we have trophosperm and podosperm; and, unfortunately, numerous other instances might be adduced. The rule to be observed in terminology is evidently this; that as no word ought to have two applications or meanings, so no idea should be expressed by more than one term; and, if a term expressive of a distinct point of structure already exists, no new term should on any account be created, from the fancy that it may be better, or more expressive, than the old one. To do so is not only unwise, but absolutely mischievous.

CHAPTER V.

OF SYNONYMES.

THE synonymes of plants are the names applied to particular species by different authors. Names are often unlike each other; in which case synonymes become indispensable to a right knowledge of a plant; but when one name only has been given by common consent, synonymes, in that case, are of less importance. The objects that they serve are these: they indicate —

1. The names of the authors who have described the species, and the place in their writings in which the description is to be found.
2. The chronology of the species, pointing out the period at which it was first made known to the world.
3. The works in which figures are to be found.
4. The various names under which it has, from time to time, been known.

Synonymes, therefore, if complete, present a brief, but very instructive, history of a plant. In monographs, or complete accounts of particular groups of plants, no synonymes of any importance whatever ought to be omitted: in more concise works, one or two of the principal are sufficient. The importance of a synonyme depends upon its being that of some author who has written, in an original manner, upon a given plant. In proportion as originality decreases, the value of synonymes decreases also.

In arranging synonymes, a strict chronological order should be maintained, beginning with the most ancient name, and ending with the most recent. But, although the citation of the names must be strictly chronological, it does not therefore follow that the quotation of the works in which the names occur should be chronological also: this would lead to great confusion and inconvenience. It has been found practically better to arrange the names chronologically; and to arrange under each name, in chronological order, those authors who have spoken of the plant by such name.

This will be more apparent from the following example, from the *Systema Naturale* of De Candolle, in which the dates of the authors' works are introduced to demonstrate the chronological order of their quotations. In practice the dates are usually omitted: it would be, perhaps, an improvement if they were always added.

TROLLIUS ASIATICUS.

Helleborus aconiti folio flore globoso croceo. *Amm. ruth. p.* 76. *n.* 101. (1739.)
Trollius asiaticus. *Lin. ! sp. pl.* 782 (*exclus. Buxb. et Tourn. syn.*) (1763.)—*Mill. dict. n.* 2. (1768.)—*Gmel. fl. sib.* 4. p. 190. *n.* 23. (1769.)—*Pall. itin.* 2. *p.* 528. (1793.)—**Curt. bot. mag. t.* 235. (1793.)—*Willd. sp.* 2. *p.* 1334. (1799.)—*Poir. ! dict.* 8. *p.* 122. (1808.)
T. europæus *Sobol. fl. petr. p.* 134. *n.* 376 ? (1799.)
T. sertiflorus *Salisb. in Lin. Soc.* 8. *p.* 303. (1809.)

In order to show distinctly the different value of these synonymes, De Candolle marks with an asterisk (*) those in which good original descriptions are to be found; and to explain which have been ascertained by the actual inspection of authentic specimens, he marks such names with a note of admiration immediately succeeding the name of the author: thus, *Lin. ! sp. pl.* 427. would mean that the original specimen from which the plant was described by Linnæus in the *Species Plantarum*, page 427., had been actually examined by himself; whereas, if the note of admiration had been omitted, it would have appeared that the only evidence, with respect to the plant described by Linnæus, was obtained from his book itself. This distinction is of great importance, as it shows upon which synonymes implicit reliance can be placed, and to which we can turn with less confidence.

In proportion to the importance of synonymes ought to be the care with which they are quoted. No synonymes ought to be adopted by a writer, upon the credit of others; he should always judge for himself; or, if that should not be in his power, he should take care to show which have been ascertained by himself, and for which he trusts to others. It is especially important never to suppose that plants are the same whose names are the same. Upon this point it particularly behoves the botanist to be vigilant; for nothing is more common than for writers to mistake the plants intended by each other. Thus, R. pimpinellifolia of Linnæus, is R. spinosissima; R. pimpinellifolia of Pallas is a distinct variety, if not species, called altaica by Willdenow; R. pimpinellifolia of Villars is Rosa alpina; R. pimpinellifolia of Bieberstein is probably R. grandiflora. Care must also be taken not to suppose that the plants with different names are different species. It frequently happens that a known species, already described by one Botanist, is described as new by another. This arises from a variety of causes: the original description is imperfect or inaccurate, so that the species to which it refers cannot be recognised; or a species may have been described by one Botanist, in a work unknown to another, who has therefore described it anew. This is an evil for which there is no other remedy than vigilance on the part of those who take the lead in science; and who, from time to time, apply themselves to purify it from the errors that are daily accumulating. So difficult, however, is it to detect repetitions, that, even in the publications of the most distinguished and skilful writers, they occur in numberless instances: for instance, the Unonas uncinata, hamata, and esculenta of Dunal and De Candolle are identically the same.

CHAPTER VI.

OF HERBARIA.

To a Botanist who studies the science with much attention, and with a view to becoming perfectly acquainted with it, neither books nor the most elaborate descriptions prove sufficient. He finds it indispensable to have continually within his reach some portion of as many species as he can procure. If he has admission to a botanical garden, a great many species may thus be readibly accessible; although, even in such a case, it is only at particular periods that he can study the flowers and fruits of any of them: a garden, too, seldom contains more than a fifteenth or a tenth of the number of known species; and far more frequently not a twentieth.

For these reasons, Botanists have contrived a method of preserving, by drying and pressure, specimens of plants which represent all that it is most essential to recognise. A collection of such specimens was formerly known by the expressive name of *Hortus siccus;* but is now universally called a *Herbarium.* If well prepared and arranged, such a collection is invaluable to any working Botanist, because it enables him instantly, at all times, to compare plants themselves with each other, and with the accounts of other Botanists; or to examine them with reference to points of structure not previously considered. It will, therefore, be useful to explain, shortly, the best modes of preparing, arranging, and preserving herbaria.

What is called the specimen of a plant is a small shoot bearing flowers and fruit, either together or separately, pressed flat and dried, so that it may be conveniently fixed upon a sheet of paper. As a plant is, in all cases, an aggregation of individuals growing upon exactly the same plan, and producing the same kind of reproductive organs, it follows that a single shoot, comprehending leaves, flowers, and fruit, is a representation of the largest tree of the forest, and will give as distinct an idea of the individual as if a huge limb were before the Botanist. It is this fact that enables us to form herbaria. Besides the dried twigs thus described, a herbarium should contain specimens of the wood of each species, and also a collection of fruits and seeds, which, being often large, hard, and incapable of compression, are not fit to be incorporated with the dried specimens themselves.

In selecting specimens for drying, care must be taken that they exhibit the usual character of the species; no imperfect or monstrous shoot should be made use of. If the leaves of different parts of the species vary, as is often the case in herbaceous plants, examples of both should be preserved. The twig should not be more woody than is unavoidable, because of its not lying compactly in the herbarium. If the flowers grow from a very large woody part of the trunk, as is often the case in some Malpighias, Cynometra, &c., then they should be preserved with a piece of the bark only adhering to them. It is also very important that ripe fruit should accompany the specimen. When the fruit is small, or thin, or capable of compression without injury, a second dried specimen may be added to that exhibiting the flowers; but when it is large and woody, it must be preserved separately, in a manner I shall presently describe.

Next to a judicious selection of specimens, it is important to dry them in the best manner. For this purpose various methods have been proposed; some of the simplest and most practicable may be mentioned. If you are in a country where there is a great deal of sun-heat, it is an excellent plan to place your specimen between the leaves of a sheet of paper, and simply to pour as much sand or dried earth over it as will press every part flat, and then to leave it in the full sunshine. A few hours are often sufficient to dry a specimen thoroughly in this manner. But in travelling, when conveniences of this kind cannot be had, and in wild uninhabited regions, it is better to have two or more pasteboards of the size of the paper in which your specimens are dried, and some stout cord or leathern straps. Having gathered specimens until you are apprehensive of their shrivelling, fill each sheet of paper with as many as it will contain; and, having thus formed a good stout bundle, place it between the pasteboards, and compress it with your cord or straps. In the evening, or at the first convenient opportunity, unstrap the package, take a fresh sheet of paper, and make it very dry and hot before a fire; into the sheet, so heated, transfer the specimens from the first sheet of paper in your package; then dry that sheet, and shift into it the specimens lying in the second sheet; and so go on, till all your specimens are shifted; then strap up the package anew, and repeat the operation at every convenient opportunity, till the plants are dry. They should then be transferred to fresh paper, tied up rather loosely, and laid by. Should the Botanist be stationary, or in any civilised country, he may dry his paper in the sun; or, if the number of specimens he has to prepare is inconsiderable, he may simply put them between cushions in a press resembling a napkin-press, laying it in the sun, or before a hot fire. It is extremely important that specimens should be dried quickly, otherwise they are apt to become mouldy and rotten, or black, and to fall in pieces. Notwithstanding all the precautions that can be taken, some plants, such as Orchidaceæ, will fall in pieces in drying: when this is the case, the fragments are to be carefully preserved, in order that they may be put together when the specimen is finally glued down. In many cases, particularly those of Coniferæ, Ericæ, &c., the leaves may be prevented falling off by plunging the specimen, when newly gathered, for a minute into *boiling* water. The great objects in drying a specimen are, to preserve its colour, if possible, which is not often the case, and not to press it so flat as to crush any of the parts, because that renders it impossible subsequently to analyse them.

Specimens of wood should be truncheons, five or six inches long, and three or four inches in diameter, if the plant grows so much. They should be planed smooth at each extremity, but neither varnished nor polished.

Specimens of fruits simply require to be dried in the sun.

When specimens shall have been thoroughly dried, they should be fastened by strong glue, not gum nor paste. to half-sheets of good stout white paper: the place where they were found, or person from whom they were obtained, should be written at the foot of each specimen, and the name at the lowest right-hand corner. If any of the flowers, or fruits, or seeds, are loose, they should be put into small paper cases, which may be glued, in some convenient place, to the paper. These cases are extremely useful; and fragments so preserved, being well adapted for subsequent analysis, will often prevent the specimen itself from being pulled in pieces.

The best size for the paper appears, by experience, to be 10¾ inches by 16½. Linnæus used a size resembling our foolscap; but it is much too small; and a few employ paper 11¼ inches by 18½; but that is larger than is necessary, and much too expensive.

In analysing dried specimens, the flowers or fruits should always be softened in boiling water: this renders all the parts pliable, and often restores them to their original position.

In arranging specimens, when thus prepared, every species of the same genus should be put into a wrapper formed of a whole sheet of paper, and marked at the lower left corner with the name of the genus. The genera should then be put together according to their natural orders.

In large collections it is often found difficult to preserve that exact order which is indispensable to the utility of a herbarium; and, accordingly, we constantly find Botanists embarrassed by multitudes of unarranged specimens. As this is a great evil, I trust that a few hints upon the subject may not be without their use; especially as, by attending to them myself, I have probably not 500 unarranged specimens in a herbarium of more than 30,000 species. — Never suffer collections, however small, to accumulate; but, the very day, if possible, that a parcel of dried plants arrives, put each in its place. For this purpose they should not be glued down; but each species, with a ticket explaining its origin, name, &c., should be laid loose upon a half-sheet of waste paper, and then put into the cover of the genus to which it belongs: if the genus is not recognised, and there is no time for determining it, then take a cover marked with the name of the order at its lower left-hand corner, and put them in it; or, if the order is not known, then put the specimens into covers marked with the names of countries instead of orders, after which you can examine them, from time to time, as opportunities may occur: in the herbarium above named, there are about 300 species thus laid by for consideration. Afterwards, when leisure permits, those generic covers in which there appears to be the greatest accumulation of loose specimens should be examined, the species compared and sorted, new species glued upon fresh half-sheets of paper, and duplicates taken out. The advantage of this plan is, that, under any circumstances, if it is wished to consult a particular order, all the materials you possess will be found, in some state or other, collected into one place. I am persuaded that, if this simple method were attended to, the confusion now so common in herbaria, and which renders so many of them almost useless, would never exist.

Fruits, if large, will be placed loose on shelves, in cases with glass fronts; or, if smaller, in little bottles, in which also seeds should be preserved; each fruit or bottle being labelled, and the whole arranged according to natural order. Specimens of wood may be conveniently combined with a carpological collection, and arranged on the same plan. When the sections of wood are very large, as is sometimes the case, there may be an extra compartment at the base of the case, in which they can be placed.

The cases in which the specimens are arranged may be made of any well-seasoned timber; mahogany is best; but pine wood will answer the purpose. They should consist of little closets, of a size convenient for moving from place to place; of which, two, placed one on the other, will form a tier. Each closet should have folding-doors, and its shelves should be in two rows: the distance from shelf to shelf should be six inches. The sides and ends of the closets should be made of ¾-inch board; but for the shelves ⅜-inch is sufficient.

To preserve plants against the depredations of insects, by which, especially the little Anobium castaneum, they are apt to be much infested, it has been recommended to wash each specimen with a solution of corrosive sublimate in camphorated spirits of wine; but, independently of this being a doubtful mode of preservation, it is expensive, and, in large collections, excessively troublesome. I have found that suspending little open paper bags, filled with camphor, in the inside of the doors of my cabinets, is a more simple and a sufficiently effectual protection. It is true that camphor will not drive away the larvæ that may be carried into the herbarium in fresh specimens; but the moment they become perfect insects they quit the cases, without leaving any eggs behind them.

In all large collections of specimens there must necessarily be a constant accumulation of duplicates: as they are of no utility to the possessor, he will, if he is a liberal man, and wishes well to science, distribute them among his friends, or other men of science, in order that the means of observation and examination, upon which the progress of science depends, may be multiplied at the greatest possible number of points. He will not hoard them up till insects, dust, and decay destroy them; he will not plead want of leisure (meaning want of inclination) for looking them out, or, when applied to for them, invent some frivolous excuse for avoiding compliance with the request; on the contrary, he will be anxious to disembarrass himself of that which is superfluous, and it will be his greatest pleasure to find himself able to supply others with the same means of study as himself. Conduct with regard to the disposal of duplicate specimens is a sure sign of the real nature of a man's mind. We may be perfectly certain, for all experience proves it, that to be liberal in the distribution of duplicates is a sign of a liberal generous disposition, and of a man who studies science for its own sake; while, on the other hand, a contrary line of conduct is an equally certain indication of a contracted spirit, and of a man who studies science less for the sake of advancing it, than in the hope of being able to gain some little additional reputation by which his own fame may be extended. A private individual has, no doubt, a right to do as he likes with that which is his own, just as a miser has a right to hoard his money, if such is his taste; but, of the keepers of public collections, it is the bounden duty to take care that every thing in their charge be rendered, in every possible manner, available for the advancement of science.

It is most honourable to the British government, and especially to the Court of Directors of the East India Company, and to the Commissioners for the Affairs of India, that this great public principle has been recognised; and I trust the day is not distant when the trustees of the British Museum will order it to be acted upon, both in spirit and in letter, by the officers in charge of the public property in that national institution.

CHAPTER VII.

OF BOTANICAL DRAWINGS.

Another important method of indicating and preserving the characters of plants is by means of botanical drawings; which, if carefully executed, and accompanied by magnified analyses of the parts that are not visible upon external inspection, are the very best means of expressing the peculiarities of a species. But, to render drawings really useful, there are many circumstances to be attended to.

In the first botanical works that were illustrated by figures, the drawings were rude, and ill calculated to convey any clear idea of the object they were intended to represent: but, as a knowledge of the science advanced, great improvement took place in their execution; minute accuracy was introduced into the outline of the leaves; the form and position of the flowers were carefully expressed; and, if the parts of fructification were neglected, it was because their importance was not understood. By degrees, the analysis of those parts began to be attended to; attempts were made, with various success, to represent the minute points in the organs of fructification. At last, the subject of carpology was taken up by the celebrated Gærtner, who published two quarto volumes, in which numerous plates represented, often in a magnified state, the internal structure of fruits, and especially of their seeds. From the appearance of this work, I think, it is, that decided improvements in the drawings of the analysis of flowers may be dated. Since that period botanical drawings have been gradually improving, till, at last, many have been executed which seem to leave nothing to be desired.

A botanical drawing should represent a branch of the plant in flower, and also in fruit, of the natural size, in which all the characters of the leaves and ramifications, the direction and relative position of parts, the mode of expansion, the arrangement of the flowers, and, in short, all that can be seen by the naked eye should be accurately expressed. It should also contain analyses of all the parts of fructification, magnified so much that every character may be distinctly seen; and this analysis, to be complete, should express the state of the organs of fructification, not only at the period of the expansion of the flowers, but in the bud state, and when arrived at perfect maturity. If to this the germination and vernation, and highly magnified anatomical representations of the tissue and internal structure of the stem and leaves, be added, the drawing may be considered complete.

But as the expense of preparing and publishing such drawings would be enormous, botanists usually content themselves with a representation of those parts only that are supposed to be most essential; such as the structure of the flower when expanded, and of the fruit and seed when ripe; and this is found, for systematic purposes, sufficiently complete, provided such details as are introduced are perfectly clear and correct.

In order to enable the student, who is interested in this subject, to form a more distinct notion of the relative utility of botanical drawings, a reference to some of the most perfect that have yet been executed is subjoined.

As instances of the highest perfection of which botanical drawings are at present susceptible, the volume of illustrations of the structure of Wheat, by Francis Bauer, preserved in the British Museum; the analysis of Rafflesia, published in the 12th volume of the *Linnean Transactions;* the drawings of New Holland plants in the Appendix to Flinders's voyage to that country, and the three fascicles of figures of New Holland plants by Ferdinand Bauer; with the microscopic drawings of the fructification of Orchidaceous plants, now in course of publication, by the former distinguished artist, may be justly said to be entitled to the first place. A high station is also claimed by Hooker's figures of British Jungermanniæ, in which great artistical skill is combined with accurate, and for the time extensive, microscopical research.

Among works in which fewer details are introduced, especial mention must be made of the drawings of Palms, and the figures that illustrate Von Martius's *Nova Genera et Species Plantarum;* Turpin's plates in Humboldt and Kunth's *Nova Genera Plantarum*, and in Delessert's *Icones Plantarum;* and some excellent analyses of the parts of fructification of Rhamnaceæ and Bruniaceæ, in his memoirs upon those orders, by Adolphe Brongniart.

Almost every scientific work of reputation, of the present day, contains figures which are formed upon the models of those now enumerated; from which they differ in the quantity of analysis that is introduced, a circumstance generally regulated by the price at which they are published.

Of anatomical plates, the best are those of Link, in his folio work on vegetable anatomy; of Mirbel, in his *Mémoire sur l'Ovule;* of Adolphe Brongniart, in his various papers in the volumes of the *Annales des Sciences;* and especially of Mohl, in his illustrations of the anatomy of Palms and Tree Ferns.

I have mentioned these as instances of good drawings, because they are easily accessible, and incontestably are well adapted to improving the taste and execution of a student; but there are other modern works, in which the figures may be also studied with great advantage. Whatever bears the name of Francis or Ferdinand Bauer, Hooker, Greville, Mirbel, Decaisne, Schleiden, L. C. Richard, Miss Drake, Mohl, or Turpin, may almost always be profitably studied.

A very ingenious method of obtaining *photogenic* drawings, or fac-simile representations of plants, by the action of light upon paper prepared with some of the salts of silver, has lately been invented by Mr. Henry Fox Talbot; and the art, if it should prove possible to use it for practical purposes, would be of great value: but too little is as yet known of its application, to enable me to speak confidently upon this point.

APPENDIX.

Page 10.

The only case of undoubtedly perforated parenchyma with which I am acquainted is in Sphagnum, where it was first noticed by Mr. Valentine (*Muscologia Nottinghamiensis,* No. 1. 1833). He correctly describes this genus as having the exterior cells of its branches furnished with an aperture communicating with the external air. "The aperture is tolerably distinct in S. acutifolium; it is situated at the upper end of the cell, and stands off obliquely, appearing like a minute truncated cone. An easy way to observe it is, to press out the air contained in the cells, which escapes from the aperture in a minute bubble." This curious contrivance might have been supposed analogous to the air passages into the trunk, below the insertion of the leaves of Tree Ferns, if it did not equally exist in all the parenchyma of the leaves themselves. Mr. Valentine does not notice the latter fact, and I believe he considers the circles in the leaves of Sphagnum not to be apertures: but I had ascertained, by Mr. Reade's ingenious charring process, that they undoubtedly are openings, before I saw John Röper's paper upon the subject in the *Annales des Sciences* (n. s. x. 314.). This writer determined that the circular spaces in Sphagnum leaves are openings, by observing the exit and entrance through them of the Rotifer vulgaris, and of minute granular matter. He considers the openings intended "to guarantee the organs of respiration from the too great influence of the air." But I do not perceive in what way such an effect is to be accomplished.

Page 32.

Spiral vessels certainly exist in the roots of many exogens; in the Parsnep and the Beet they are large, and readily extracted entire.

With regard to their existence in seeds, Mr. Quekett has favoured me with the following memorandum (March 13. 1839):—

"If you place almonds in boiling water, and separate the testa, and while thus softened you scrape or remove some of the veins which figure its surface, it will be found that they are almost wholly spiral vessels, which are of rather minute dimensions.

"There is something else curious respecting this seed. On its surface are numerous projecting cells which have very thick parietes: these can be found burst and their contents emitted; in fact they look more like eggs of some minute insect, which however they are not, as I have examined seeds of unopened almonds, where they exist likewise: they appear to me to be analogous to the cells which exist on the seeds of Cobæa scandens, which Don describes as *nectaries*, but which is, instead, a beautiful example of fibro-cellular tissue."

To this I may add, that in the seed of Soymida febrifuga there lies in the middle of the wing a thick stratum of fibro-cellular bodies, which would be regarded as spiral vessels if they were longer and more cylindrical; but which seem to be a curious and distinct form of fibro-cellular tissue.

Page 43.

In addition to the remarks here made upon Raphides, I have the satisfaction to insert in this place the following interesting communication from Mr. Quekett, upon the same subject: —

"*General Appearance.* — Raphides are most frequently observed under two forms, appearing in one instance as transparent acicular crystals, which are either distinct from each other or united into a compact fibrous bundle, and in the other instance as small bodies composed of many crystals which radiate from the same centre, thereby forming a more or less spherical mass.

"Besides these two usual kinds, there are other forms, but of more rare occurrence, some of which are observed of regular crystalline figure; as the rhombohedron in some cells of Calla æthiopica, and bark of Cascarilla: octohedron, according to Meyen, in the stem of Tradescantia virginica: the rectangular prism in Quillaja saponaria; and oblique prisms, which occur with acicular crystals, in Scilla maritima: but still there are a few varieties which present an irregular crystalline figure, some of which can be observed also in Tradescantia virginica, and in the inner layers of the bark of the Lime tree, where they seem very thin and pointed at the extremities, appearing like slices cut longitudinally from the middle of a square prism, which may be imagined to possess a four-sided pyramid at each end.

"*Form.* — With respect to the form of the *acicular Raphides*, some difference of opinion exists between Raspail and Mohl's description; the former asserting that they are six-sided prisms, terminated at each end by a pyramid with the same base; whilst the latter describes them as *right-angled* four-sided prisms, vanishing into points. It is a difficult matter to decide between these two opinions, if an entire crystal be the subject of examination; for, even if magnified 1000 times, the figure is not clearly defined: but, by having recourse to some delicate manipulation, the proper shape can be then ascertained, when it can be shown that neither of the two opinions is correct in all points.

"Raspail's reason for considering the acicular crystals to be hexagonal prisms arises from the appearance they present with transmitted light, when some (but not all) are seen to exhibit two dark margins and a streak of light between them, which extends the whole length of the crystal: from this he reasons that its figure is six-sided, the lateral planes reflecting the light which impinges upon them, and consequently are seen as darkened margins, whilst the surfaces which are superior and inferior, being in a position favourable for the transmission of the rays, are transparent. This is the argument brought forward in Raspail's *Organic Chemistry*, in favour of the hexagonal figure, but there are no attempts to prove if any other form or position of an acicular crystal could not present a similar aspect, which is the case, as will be shown hereafter.

"As respects the summit being a six-sided pyramid, its existence does not seem discoverable, for the crystal from about its centre gradually vanishes to a point, having no angular interruption, such as is observed in the large crystals in the root of Iris florentina or the wood of Quillaja, where a regular right-angled prism is surmounted by a pyramid. Mohl's idea of the shape certainly approximates the truth more than Raspail's; but it can be shown, though the acicular crystals are four-sided, they are not always *right-angled* prisms, as he asserts. To witness these facts the crystals, must be obtained, by lengthened maceration, free of cellular tissue, and then crushed into fragments, when many will present an obliquely transverse fracture, which exhibits tour sides, some having the angles right angles, and others acute and obtuse angles; in fact, the transverse section of such would resemble frequently a rhombus To examine more satisfactorily the fractured ends of these minute crystals, which scarcely measure the $\frac{1}{10,000}$ part of an inch, it is most convenient to place their fragments in a watch glass, with a small portion of Canada balsam, and to heat the whole till the balsam has acquired a viscid consistence, then let it be removed from the source of heat, and be stirred whilst the mass is cooling till sufficiently hard, when the broken Raphides will be sustained in it in all directions; and frequently a few can be observed erect, which cannot fail to give a true outline of their real form, which by this method appears to be a four-sided prism, the angles being frequently oblique, and in other instances to put on the rectangular condition. Occasionally some of the crystals are observed to exhibit a triangular section of the isosceles shape, which seems to be an anomaly: but, to account for this, it is to be remembered that it is not opposed to the laws of crystallisation for certain bodies to crystallise in halves, consequently the half of a four-sided prism, taken from one angle to the opposite one, would be triangular; and it is conceived that when a crystal exhibits this triangular section it has belonged to the compact bundle of crystals in which it has been constrained to assume this form, as being fitted to fill up certain spaces better than one of the oblique or rectangular shape.

" This being the observed figure, it is not difficult to account for the black margins observed in certain crystals, which may be occasioned by a rectangular prism resting obliquely, or by an oblique or triangular prism, as well as by the hexagonal; for, as the sides of either are not in the plane of direction of transmitted light, the rays are reflected, and that portion which reflects the light appears dark.

" Besides these methods of determining the form of acicular raphides, if a little alcohol be added to water containing them, and examined immediately after by the microscope, the crystals can be often seen to roll over and over, and some of them will, whilst revolving, present alternately a pointed and then a flat extremity, just as if a wedge were revolving on its axis; showing that such crystals are four-sided, but two of the sides only attenuated to form the pointed appearance, the other two suffering no diminution of their breadth at any point.

" That the four-sided prism is the ultimate figure of these minute crystals is rendered more probable by the occurrence of rhombohedral and rhombic prisms without pyramids, of the same composition, in the same plant, but of much greater widths; and there can be no doubt that these latter bodies and the acicular are two modifications of crystal of the same substance. The most decided proof of their being four-sided is obtained by pressing lightly on the piece of glass which covers them, whilst examined under the microscope, when those which appear six-sided instantly appear four-sided, owing to the square crystal resting obliquely: this can be seen in the minute crystals of Squill, or in the large square ones of Quillaja saponaria.

"The rounded masses, which may be termed *Conglomerate Raphides* in opposition to the acicular variety, seldom present more than the pyramid of each little crystal composing them; but in a few cases, where an opportunity is afforded of examining the prism, it can be seen to be rectangular and terminated by a four-sided pyramid.

"*Classes of Plants in which they are found.*—No division of the vegetable kingdom seems without more or less quantities of these crystalline formations, which are found in a great number of Exogens and Endogens, and likewise in Acrogens, being visible in Ferns and Mosses, and, according to Unger, in the lowest of the Algaceæ, as Nostoc Muscorum, and Conferva crystallifera.

"The frequency of occurrence of these bodies is such, that it appears that, instead of those plants containing them being exceptions, those are to be considered such which have none in their tissues.

"It does not appear, from numerous observations, that the acicular and conglomerate Raphides are equally common in the several classes of Plants; but that Exogens contain perhaps the one kind as often as the other, while Endogens undoubtedly contain most often the acicular variety.

"*Situation.*—The position of these bodies has been a subject of controversy; Raspail asserting that they are always in the intercellular passages, whilst Turpin, Meyen, and Unger maintain that they are universally in the interior of the cells, which latter opinion is easily proved to be nearly correct by a little careful dissection of any plant containing them.

"Raspail's advice to see these bodies is to tear a piece of the Hyacinth stem in a drop of water placed on the stage of the microscope, when numbers of acicular crystals will be visible (this method is not likely to show them in the interior of the cells); and from measuring he finds the length of the crystal longer than the ordinary cells of the tissue; and therefore he decides from this, that they cannot be contained in the interior of the cells, while he overlooks the fact that the cell in which they are contained may be often dilated to five or six times the size of those composing the ordinary tissue of the plant. The square crystals in Quillaja saponaria appear as if loose in the plant, but they are really in a cell, which cell is applied closely to the surface, the crystal completely filling it: when muriatic acid is added the crystal is dissolved, and the cell is left visible.

"The most ready method of determining that the acicular crystals are contained within the cells is, to take a piece of the bulb of Scilla maritima and macerate it until it becomes decomposed, or to take some of the rotten portions which are frequently on its exterior; and, by examining either of these with the microscope, it will be seen that there are numbers of isolated cells which contain crystals, which cells are five or six times larger than those of the tissue which have none within them; and, what appears remarkable, the crystals seldom occupy more than a small portion of the cell though it be so dilated, and in the Squill are usually collected at one end, probably by gravitation; but in the biforines they generally completely fill a small portion of the cell, about its middle, the ends containing none whatever.

"To prove the same fact as regards the conglomerate kind, let a piece of the root of Rhubarb, or a part of the frond of Zamia pungens, be boiled till the cohesion of the tissue be destroyed, when some of the separated cells will exhibit one cluster generally in each; but the containing cell is not larger than others of the same plant, and at times very little larger than the mass within it.

"There are some exceptions to Raphides being found constantly in cells, notwithstanding Unger's assertion that they are exclusively found in their interior, and that the vascular bundles have none within them: for they can be observed in the interior of the vessels in the stem of the Grape vine; and loose in the anthers, mixed with the pollen, in Hemerocallis purpurea, Anigozanthus flavidus, and many other plants; and they can be observed in the air cavities of and many aquatics.

"The interior of the *Stem* is the most common situation in the herbaceous plants for Raphides, and it used to be considered the only locality; but the epidermis of the stem of many plants displays thousands, as that of the Tradescantias, Opuntia crassa, others.

"The *Bark* of many trees also contains them; they are readily observed in the layers of the Lime tree bark, of two kinds: also in the barks of Araucaria imbricata, Cascarilla, Cinchona, and various other plants.

"Even the *Pith* is not destitute of crystals; for the Grape vine exhibits them in that situation, as does the Lime tree in the medullary rays, which are processes connected with it.

"The *Leaves* of multitudes of plants contain the various kinds in great abundance; Pisonia, Hemerocallis, and Calla æthiopica furnishing the acicular, whilst Rheum palmatum and undulatum are common examples yielding the conglomerate.

"The *Stipules* are not without Raphides, for those of the Grape vine show them in situ, but very small in size.

"The *Sepals* of many Orchidaceæ abound with crystals, as those of Bolbophyllum fuscum and others, and especially the horny labellum of Catasetum.

"The *Petals* of many plants, like the sepals, contain more or less crystalline matter, which is particularly evident in the small corolla of the Grape vine.

"The *Fruit* does not so often contain them, yet the common Grape furnishes a sufficient evidence of their existence in that organ.

"In the *Root* their presence can be easily discovered, especially in all Rhubarbs, varying a little in number from the locality of the specimen; most in Turkish, less in East-Indian, and least in British-grown specimens.

"*Number in a Cell.* — The number of Raphides in any cell is subject to much variation. It is seldom that a single crystal is met with; but in the Squill, Calla æthiopica, and other examples, besides the multitude of acicular crystals, some cells which are not dilated occasionally exhibit only one minute rhombohedron, as has been observed by Unger in Papyrus antiquorum. Of the *conglomerate* kind, one cluster is the usual number in the respective cells, though in Zamia pungens two such can be at times observed within the same cell. The *acicular* Raphides are in the greatest numbers, and vary somewhat in quantity in different cells and in different plants; some containing but very few, whilst others contain hundreds.

"*Proportion to the Weight of Tissue.* — The mass of crystalline matter that is formed in the tissue of some plants is prodigious, whilst in others the quantity is very thinly diffused. In several species of Cactaceæ the crystals equal if not exceed the weight of dried tissue; this is especially the case in Cereus senilis. In Turkey rhubarb root, one hundred grains yielded between thirty-five and forty grains of Raphides; and the fact of various rhubarbs giving different feelings of grittiness to the teeth when chewed, is said by Guibourt to be employed as the test of their goodness. In the bulb of Scilla maritima, not more than ten grains are contained in the same weight of dried tissue.

" *Size.* — The acicular vary exceedingly in their measurement, some being not more than $\frac{1}{1000}$ part of an inch in length, whilst others will be as much as $\frac{1}{40}$. The conglomerate form is not subject to so much variation, varying only from $\frac{1}{50}$ to $\frac{1}{250}$ part of an inch. The size of the rhombohedral and other forms of crystals has no uniformity as to measurement, some being not more than $\frac{1}{2000}$, whilst others are the $\frac{1}{40}$ part of an inch.

" *Composition.* — According to Raspail, the composition of the acicular and conglomerate forms differs, the former being phosphate, whilst the latter are oxalate of lime. Unger mentions that Buchner, Nees von Esenbeck, and others, have found that their bases are sometimes lime, magnesia, and silica, the latter not often occurring; and that these bases are united to carbonic, oxalic, and phosphoric acids. The whole of these assertions are more or less correct, but Raspail has only given us negative proofs of their composition. It is not difficult to obtain positive ones, by the following experiments: —

" If Raphides of the conglomerate form (perfectly free from cellular tissue) be heated red hot, it will be observed that they at first become black and again white, as the heating is continued to redness: in this state they readily dissolve in weak nitric or hydrochloric acid, with effervescence; if to this solution oxalate of ammonia be added, a copious white precipitate is obtained, which indicates that the base in this case has been lime. In detecting the acid united with the lime, the proceeding is a little more complicated. For this purpose the crystals are to be dissolved in dilute nitric acid, which occurs without effervescence; to this solution nitrate of silver is to be added, when a heavy white precipitate is produced, which, when washed with distilled water to free it from any excess of acid and nitrate of silver, is to be dried; if after this a small portion be heated in the flame of a lamp it explodes, by which it is proved that the precipitate is oxalate of silver. These results, which may be performed with certainty with conglomerate Raphides, plainly proves their composition to be oxalate of lime.

" The acicular can be demonstrated to be phosphate of lime, by proceeding thus. If heated red hot, they do not dissolve in acids with effervescence, a fact which essentially distinguishes the composition of the two kinds. When dissolved in dilute nitric acid, if oxalate of ammonia be added, we have the characteristic precipitate of lime; if with a portion of the acid solution be mixed a little nitrate of silver, a white precipitate is not obtained, as in the last case, but one of a lemon colour, which is such as denotes the combination with silver of phosphoric acid, which must have been furnished by the acicular Raphides.

" Though phosphoric and oxalic acids united with lime are found the most frequent components of these minute crystals, there can be no doubt that tartaric acid enters into their formation in certain plants, as in the fruit of the Grape, where the crystals are found of a different figure from those in the interior of the leaves or stem; and also that *magnesia* can be frequently detected combined with lime, and perhaps never forms crystals with acid, without lime entering also into their composition.

" *Silica*, though it frequently forms an organised part of vegetables, seldom exists as crystals in their interior. In a bark from Para, which is said to be manufactured into a kind of pottery, silica exists in abundance in granular fragments, which, however, do not put on a crystalline form.

" *Conclusion.*—It is not known what purposes these bodies fulfil in the economy of plants, but it has been conjectured, since amylaceous matters are deposited, and again appropriated for the support of the carbonaceous portion of the tissue, according to the necessities of the individual, that these crystals may be deposits to be applied towards the mineral part or skeleton of the plant, as occasion may require: but it has been found from experiments that these calcareous bodies are insoluble in vegetable acids, and the silica of course in every thing; consequently they cannot be taken up again, are therefore unsuited to the vital exigencies of the vegetable, and probably are of no use, even mechanically, in the several tissues which contain them, because plants of many kinds do not secrete such formations: therefore, it will be nearer the truth to regard them, as Link has done, as nothing more than accidental deposits.

" In all the analyses lime has been found the greatest constituent of these bodies: and since this material is so intimately associated both with animal and vegetable organisation, as not perhaps to be wanting in any individual of either kingdom, there is every reason for its being so generally the base of such crystals. Moreover, since it is the property of some vegetables to combine, out of their materials of sustenance, varied proportions of oxygen and carbon, which, when apportioned in the ratio of three of the former to two of the latter, form oxalic acid, the presence of that agent in a plant, in contact with lime, can scarcely fail in producing a crystalline substance with it. Again, as phosphoric acid is a frequent accompaniment of animal and vegetable organisation either introduced with the food, or created out of it, (it being yet a problem to solve how this and other elementary matters are produced,) it can be readily conceived why compounds with it and lime should be formed as well as with the former acid; because, as the earthy and other matters are absorbed from the moisture of the soil, they must necessarily meet with these acids when they exist, and the vitality of the plant does not prevent their forming the crystals which have been here described; still there are some curious points connected with their production. If oxalic or phosphoric acid be added to a solution of lime, instead of crystals, a pulverulent opaque precipitate is obtained, which does not happen in the interior of the plants: therefore various experiments have been devised, to discover the method of making crystals by combining the above substances. Some have been ineffectual, such as making a plant, which contains lime in its composition, absorb water with a small quantity of oxalate of ammonia dissolved in it: from the want of temperature which would create a necessity for moisture in the plant this experiment failed. A method, however, which succeeded was, to connect a vessel containing a solution of oxalate of ammonia with one containing lime water, by means of a few fibres of cotton: this gradual introduction of one fluid to the other formed perfect crystals of oxalate of lime on the ends of the fibres which were in contact with the lime water. This having succeeded, another attempt was made to form them in the interior of the cells of such plants as did not previously possess them: some difficulty occurred in finding any one fitted for the purpose, and at last Rice-paper, as it is termed, (the concentric slice from the pith of Æschynomene and Hibiscus,) was selected as the best material for the experiment, from its admitting an examination of their formation, by becoming transparent when charged with fluid.

" This substance was placed in lime water under an air pump, and the cells were soon filled with that fluid; it was then dried and submitted two or three times to the same process: by this means the cells were well charged with lime. Portions of this substance were placed in weak solutions of oxalic and phosphoric acids, and allowed to remain. On the third day, when examined, the cells in both instances contained much precipitate, together with numerous crystals; those in the oxalic acid being precisely like the conglomerate form in Rhubarb, and those in the phosphoric being rhombohedra, but none of the acicular shape were found, even after continuing the process beyond eight or ten days.

"These experiments distinctly prove the origin of Raphides, which appear to be compounds that become crystallised merely by the slow admixture of their constituents, and are probably modified by gummy, amylaceous, and other matters which are contained in the juices of the plant. Their formation does not seem confined to living structures or to any particular tissues or organs of a plant; but the process may be carried on in any situation, as can be proved in the Grape vine, in which crystals can be discovered in every organ, and in the vascular as well as in the cellular tissue."

Page 44.

In addition to the observations of Fritzsche upon the organisation of starch, M. Payen has lately published an elaborate memoir upon the same subject. He finds the granules varying in size between the $\frac{185}{1000}$ of a millimetre in the Potato, and the $\frac{2}{1000}$ of a millimetre in the seed of Chenopodium Quinoa. When crowded within the cells that generate them they become polyedral, but if floating in a thin fluid their common character is to be rounded. They are composed of successive thin layers, formed over each other, round a hilum or point of attachment to the wall of a cell: the matter of which they consist is of a uniform nature, and is formed by addition to the *interior* into which it penetrates through the hilum, the external layers being the oldest and toughest, and often thickened by being coated with other matter, such as vegetable mucus, calcareous salts, a fixed oily matter, and essential oil; this additional matter is what has given rise to the opinion that grains of starch have a peculiar integument. Amylaceous matter may be found in all the organs of plants, under favourable circumstances, except in their nascent state; the spongioles, very young leaf buds or flower buds, and the interior of the unimpregnated ovule are always destitute of starch. M. Payen has not found it in vessels or in intercellular passages, nor in the epidermis, and it is generally absent in the strata of immediately subjacent parenchyma. It is in the more interior parts, removed from the direct action of air and light, that it is principally met with, and especially in roots and underground forms of stem. (*Mémoire sur l'Amidon:* 8vo; Paris, 1839.)

Page 46.

In the tubercular roots of terrestrial Ophrydeæ, such as those which form the salep of the shops, I have shown that there are large cells filled with a matter as clear as water, and apparently of the nature of bassorin; and that this bassorin-like principle is composed of minute cells, each with its cytoblast, so compactly aggregated in the interior of the parent cell, that from this circumstance, and from their very equal refracting power, they form an apparently homogeneous mass.

Page 58.

Mohl has examined the stomates of Hyacinthus orientalis in their progress of developement. He finds them in their earliest stage a single quadrangular cell, rather broader than long, and either empty or filled with green molecular matter. In the next stage, this single cell is cut in two by a partition which is directed across the smaller diameter, and separates the molecular mass into two equal parts. At a third stage, the angles round off, and the partition is seen to be double, with an opening in its middle. Later still, the molecular mass is broken up into granules of chlorophyll, the original cell is become oblong, the passage through the double partition has acquired its full size, and the stomate is complete. (*Linnæa*, xii. 544. t. 5.)

Page 210.

In a valuable paper upon the successive formation of the parts constituting the fructification of Leguminosæ, the authors, Messrs. Schleiden and Vogel, have clearly shown that in that case the carpellary leaf is originally a folded scale, and that when the ovules appear it is from the margins of that leaf, and not from the central point of the axis; so that it seems clear that the latter must be considered the origin of ovules only in certain instances. (*Beiträge zur Entwickelungs-geschichte der Blüthentheile bei den Leguminosen.*)

Page 220.

The observations made by Mr. Griffith upon the ovule of Loranthaceæ and Santalum have been followed by others on the part of M. Decaisne, who finds that in Thesium the structure of the ovule is of the same nature as that of Santalum. (*Comptes rendus*, viii. 203.)

Page 270.

The spermatic animalcules mentioned by Meyen are figured by him in the *Annales des Sciences*, n. s. x. 319. t. 3., from Marchantia polymorpha, Chara vulgaris, Sphagnum acutifolium, and Hypnum triquetrum.

Page 295.

M. Payen, in a second memoir upon this subject, names the unchanged primitive tissue of plants *cellulose*, and says it has the same composition as starch; the matter of lignification he regards as the true lignine of chemists. (*Comptes rendus*, viii. 52.)

Page 344.

The observations by Mr. Griffith on Indian Loranthaceæ have been continued by M. Decaisne upon the common Mistletoe; and he finds that, although that plant flowers in the months of March and April, the ovule does not make its appearance earlier than the end of the month of May, or the commencement of June. (*Comptes rendus*, viii. 202.)

Page 347.

All these statements have now been copiously illustrated by excellent figures in Schleiden's memoir *Ueber Bildung des Eichens, und Entstehung des Embryos bei den Phanerogamen.*

Page 368.

There are some secondary forms under which nutritive matter is provided for plants, the most important of which is starch. The purpose which nature intends this almost universally diffused substance to answer, in the system of vegetation, is essentially nutritive. It is formed in plants soon after their parts become organised, and it collects there till in some instances, such as albumen, tubers, rhizomata, and the cellular part of endogenous stems, it forms the principal part of the mass. In such cases it is ready to be chemically changed at a fitting period, and to become the food of the germinating embryo, or of young stems and leaves. According to M. Payen, it is enabled to execute this important purpose, by virtue of its gradual solution by water and diastase, which convert it into dextrine and sugar, and thus render it capable of percolating the surrounding tissue, and passing from chamber to chamber of parenchyma. (*Mémoire sur l'Amidon*, p. 131.)

Page 351.

According to Payen (*Comptes rendus,* viii. 60.), those manures are the most efficient which are richest in nitrogen, for he considers that plants are generally able to obtain, in most cultivated soils, a sufficient supply of the other principles necessary to their existence, without the addition of manure. But this does not quite agree with an assertion of Boussingault, that although some plants rob the air of a considerable quantity of nitrogen, yet others do not assimilate it at all. (*Ib.* 55.)

Page 380.

Mr. Rigg has investigated the connection between nitrogen and plants, the results of his enquiries being given in the *Philosophical Transactions* for 1838, p. 395. &c. He finds the youngest parts of plants richest in nitrogen, the germ of Peas and Beans containing by weight about 200 parts of that gas for 1000 parts of carbon, while the cotyledons contain only from about 100 to 140 parts. He is disposed to believe that those seeds of the same kind, which contain the largest quantity of nitrogen, germinate the earliest. Alburnum he finds to contain more nitrogen than duramen, and fast-growing timber more than slow-growing, whence he infers that nitrogen exercises its influence in causing decomposition. The latter opinions he considers to be rendered still more probable by the proportion of nitrogen found in different species of wood, *cæteris paribus:* thus in satin wood and Malabar teak, both timber of great durability, the quantity of nitrogen is almost inappreciable; in Dantzic and English oak, the quantity is also very small; in American birch which soon decomposes, nitrogen is found in large quantities. Mr. Rigg finds nitrogen in large quantities in Vine leaves when they first make their appearance: as they are developed it decreases in proportional quantity; is in excess during the period of most rapid growth, and towards the close of the year it is comparatively small. He states the full-blown petals of the Rose to contain 24 parts of nitrogen in 1000 of carbon, while the unexpanded and central petals contain 66 parts.

In another paper also published in the *Philosophical Transactions* for 1838, p. 403., Mr. Rigg has considered the evolution of nitrogen during the growth of plants, and the sources from which they derive that element. He states that his enquiries all tend to prove that nitrogen is evolved during the healthy performance of the functions of plants; that the proportion which it bears to the oxygen given off is influenced by the sun's rays; but that owing to the necessary exclusion of the external atmosphere during the progress of experiments, it is impossible, with any degree of accuracy, to calculate the volume of these evolved gases during any period of the growth of plants in their natural state. If to this indefinite quantity of nitrogen given off by plants, there be added that definite volume incorporated into their substance, the question arises, whence do plants derive their nitrogen, and does any part of it proceed from the atmosphere? This problem Mr. Rigg has endeavoured to solve by a series of tabulated experiments upon seeds and seedling plants, the result of which is a large excess of nitrogen in the latter, and under such circumstances of growth that he is compelled to fix upon the atmosphere as its source. He has also arrived at the conclusion, that the differences which we find in the germination of seeds and the growth of plants in the shade and sunshine, are due in a great measure to the influence of nitrogen.

EXPLANATION OF THE PLATES.

[illegible]

PLATE I.

[illegible]

[illegible]

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FIG. 3. [illegible]

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Fig. 2.

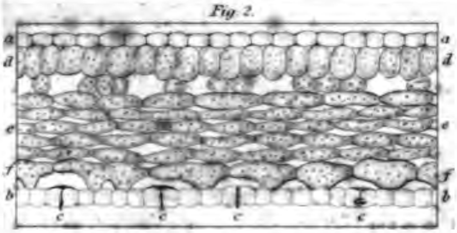
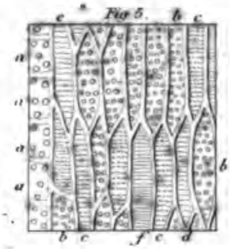


Fig 3

g 4

Fig 5.



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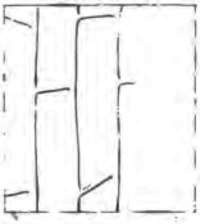

Fig 7

Fig 8

Fig 9

Fig 10

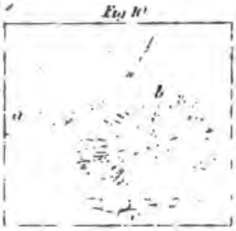

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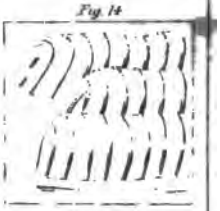
Fig 12

Fig 13

Fig. 14



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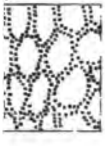


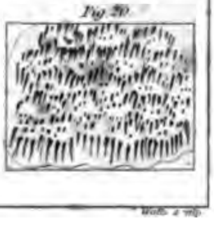
Fig 16

Fig 17

Fig 18

g 19

Fig 20



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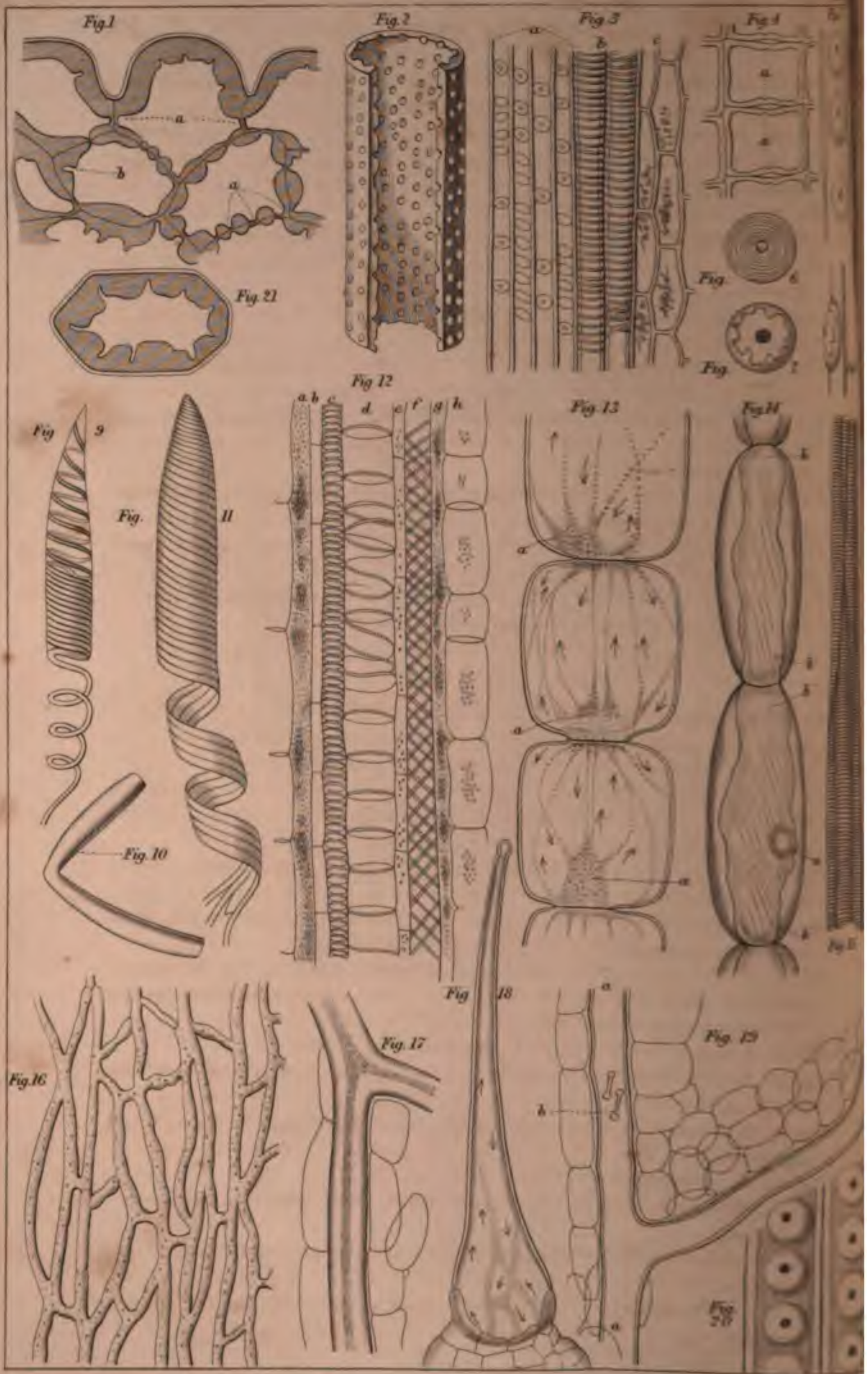

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Fig. 10. *a*, Stellate hairs from the leaf of a species of Hibiscus; *b*, a scale of the calyx of Elæagnus argentea; *c*, a hair of Chrysophyllum Cainito.

Fig. 11. Reticulated cellular tissue from the testa of Maurandya Barclayana.

Fig. 12. Spiral oblong cellules lying among the parenchyma of the leaf of Oncidium altissimum.

Fig. 13. Deep columnar cellules, with parallel fibres, from the endothecium of Calla æthiopica, the top of each cell being flat; after Purkinje.

Fig. 14. Arched fibres, connected by a membrane, in the endothecium of Nymphæa alba; after Purkinje.

Fig. 15. Flat oval cellules, with marginal incisions, in the endothecium of Phlomis fruticosa; after Purkinje.

Fig. 16. One of the elastic fibres upon the testa of Collomia linearis, unrolled spirally, and lying within its mucous sheath; magnified 500 times.

Fig. 17. A part of one of the elaters of a Jungermannia, showing a broad spiral fibre loosely twisted inside a transparent tubular membrane, with a dilated thickened mouth.

Fig. 18. Convex membranes, with lateral radiating fibres, forming together imperfect cells, in the endothecium of Veronica perfoliata; after Purkinje.

Fig. 19. Radiating fibres, in the place of cellules, in the endothecium of Polygala Chamæbuxus; after Purkinje.

Fig. 20. Prismatical depressed cells, with straight fibres on the walls, from the endothecium of Polygala speciosa; after Purkinje.

PLATE II.

Fig. 1. A section of pitted cellular tissue, showing on one side the matter of lignification separate from the elementary membrane; in the lines where the cells unite this is not shown, the membrane being so thin as to be inappreciable: *a a a* are pits in the sides of cells, corresponding with similar pits in the neighbouring cells; *b* shows that the pits are sometimes depressions without any thing to answer to them on the opposite side.

Fig. 2. An ideal figure of part of a tube of bothrenchyma, showing that the apparent holes are mere pits in the interior.

Fig. 3. A section of coniferous wood: *a*, glandular pleurenchyma; *b*, spiral vessels; *c*, prismatical parenchyma, containing chlorophyll.

Fig. 4. A transverse section of two complete tubes of glandular pleurenchyma, to show that the glands are thin spaces in the sides of contiguous tubes, through which light passes in the direction of *a a*.

Fig. 5. A front view of coniferous glands in a young state.

Fig. 6. A very highly magnified view of such glands, showing that their surface is marked by concentric circles.

Fig. 7. A front view of a coniferous gland, partially covered by the matter of lignification.

Fig. 8. A profile view of the same.

Fig. 9. A simple or one-threaded spiral vessel, partly unrolled, with its termination.

Fig. 10. A bent portion of the spire of the latter, to show that elementary fibre is cylindrical.

Fig. 11. A compound or many-threaded spiral vessel, partly unrolled, with its terminations.

Fig. 12. A longitudinal section of a portion of a stem, showing various kinds of tissue: *a* and *g*, tubes of cinenchyma or laticiferous tissue; *b*, cylindrical parenchyma; *c*, an annular duct; *d*, an annular duct of larger size, with its spires more broken; *e*, cylindrical parenchyma containing amylaceous granules; *f*, a reticulated duct; *h*, oblong parenchyma containing amylaceous granules.

Fig. 13. Joints of a hair, showing the capillary cinenchyma in which cyclosis takes place; *a*, cytoblasts; the arrows indicate the direction of the currents.

Fig. 14. Two joints of a hair of Tradescantia in a dead state, to show the collapsed appearance of the cells (*b b*) which are enclosed within the external cavity of organic mucus, and over which the currents of cyclosis are maintained; *a*, a cytoblast.

Fig. 15. A bundle of closed ducts from the stem of a Lycopodium; after a preparation by Mr. Griffith. Here is seen the manner in which such vessels are packed *in situ*, together with their terminations.

Fig. 16. A portion of cinenchyma, or laticiferous tissue, from the stipule of the Ficus elastica, showing the anastomoses; after Schultz.

Fig. 17. One of the anastomoses of cinenchyma, surrounded by thin-sided oblong parenchyma.

Fig. 18. A stinging hair, in which cyclosis is going on, the direction of the currents being indicated by arrows.

Fig. 19. An anastomosis in the cinenchyma of a Euphorbia, with two of the double-headed bodies supposed to be amylaceous; *a a* represent the mouths of the cinenchyma.

Fig. 20. Glandular pleurenchyma of Sphærostema propinquum.

PLATE III.

Fig. 1. A cluster of six-sided air-cells from the stem of Limnocharis Plumieri; they are formed entirely of prismatical cells; *a a*, partitions dividing the air-cells in two.

Fig. 2. A partition or diaphragm of the last-mentioned plant, showing the open passages that exist at the angles of the cells. When dry, the rims of the passages are dark, as at *a*; when immersed in water, the dark rim disappears, and the whole partition has the uniform appearance of *b*.

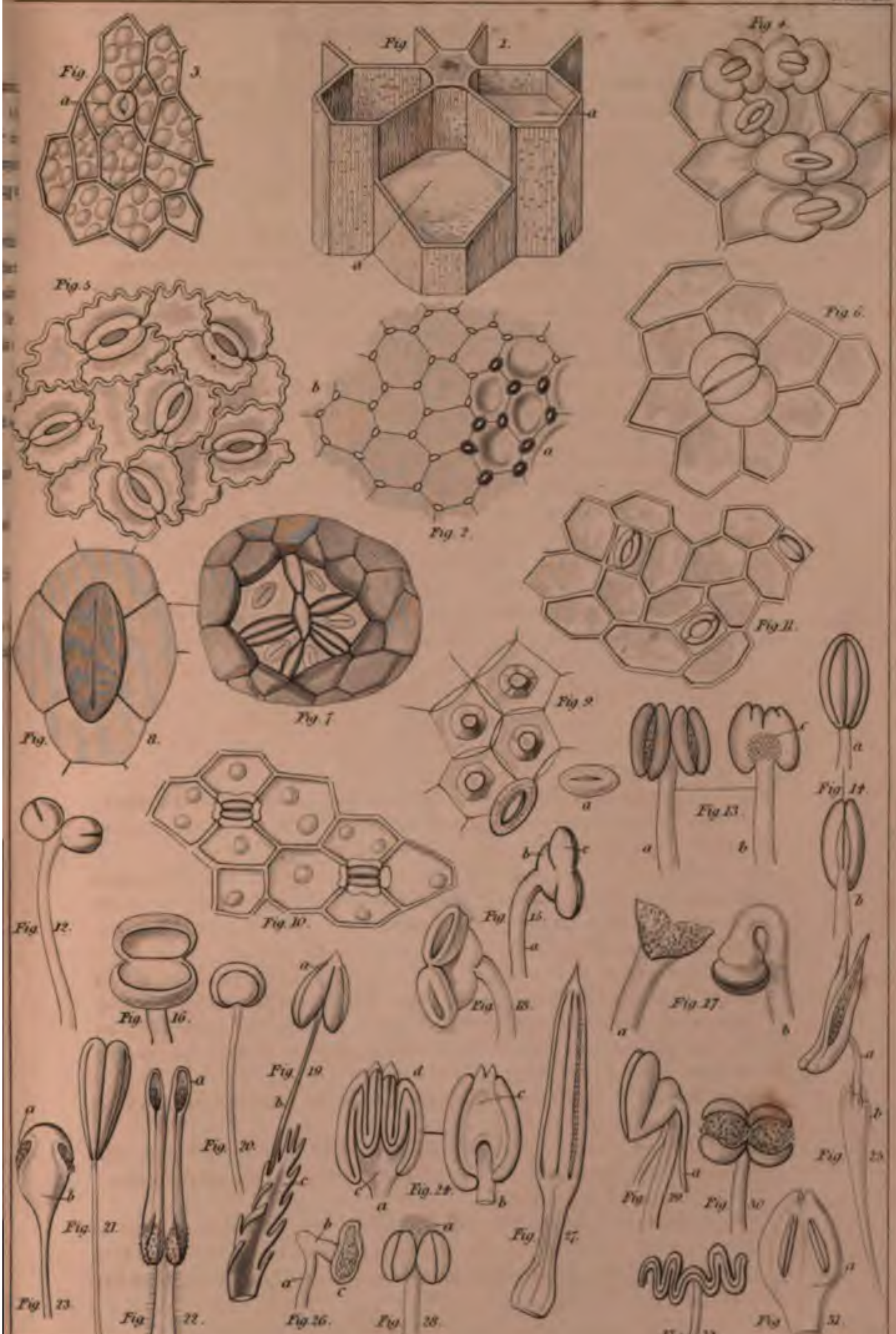
Fig. 3. A portion of the epidermis, and a stoma, of the leaf of Oncidium altissimum; *a*, the stoma, formed of two parallel glands or cells, which open by curving outwards. In this plant the stomata are very minute and few; on the membrane of each mesh of the epidermis are found sticking from four to six spherical semi-transparent green globules.

Fig. 4. Stomata of Strobilanthes Sabiniana. They are very large, and crowded together in an irregular manner.

Fig. 5. Ditto of Croton variegatum: this is an instance of an epidermis with sinuous lines. The orifice of each stoma is closed up with brownish matter.

Fig. 6. A stoma of Canna iridiflora.

Fig. 7. A cavity beneath the epidermis, in the parenchyma of Begonia sanguinea seen from the inside, so that the epidermis is farthest from the eye. It is divided by sub-cylindrical cellules into five spaces, in each of which there lies a stoma.



J.L. del.

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Fig. 8. One of the stomata of the same, more magnified, and showing that the medial line does not touch either end, and that the cavity of the stoma is filled with granular matter.

Fig. 9. Stomata of the under side of the leaf of Caladium esculentum, with a portion of epidermis. These appear to be somewhat angular cellules, occupying the centre of every area of the epidermis. The stoma consists of an oval space, in the centre of which is a narrow cleft, with a border distinctly coloured orange or brownish, and having no communication with the circumference; the space between the cleft and the latter filled with a pale green granular substance. The cleft is sometimes seen closed, as at *a*, and then there is scarcely any appearance of a border.

Fig. 10. Epidermis and stomata of Yucca gloriosa; the latter lie in square areolæ, and consist of two parallelograms lying parallel with each other. Small spheroidal bodies, having a luminous appearance under the microscope, stick here and there to the inside of the epidermis.

Fig. 11. Stomata of Limnocharis Plumieri. These also lie in square areolæ, but they have the ordinary structure: they are found in different degrees of openness, or even quite closed, upon a small piece of the same specimen.

Fig. 12. Stamen of Lemna trisulca: anther bursting vertically.

Fig. 13. Stamen of Polygonum Convolvulus: *a*, seen in front; *b*, from behind; *c*, the connectivum of the anther.

Fig. 14. Stamen of Corræa alba: *a*, seen in front; *b*, from behind.

Fig. 15. Stamen of Stachys sylvatica: *a*, filament; *b*, connectivum; *c*, anther, its lobes separated at the base by the connectivum.

Fig. 16. Anther of Alchemilla arvensis; one-celled, and bursting transversely.

Fig. 17. Stamen of Scrophularia chrysanthemifolia: *a*, part of the filament, and the anther, which is one-celled, after bursting; *b*, the same, before the dehiscence of the anther.

Fig. 18. Anther of Lamium album; its lobes, as in fig. 16., separated at their base by the large connectivum.

Fig. 19. Stamen of a species of Zygophyllum: *a*, the anther; *b*, the filament; *c*, the scale to which the filament adheres.

Fig. 20. The one-celled anther and filament of Callitriche.

Fig. 21. The stamen of Sparganium ramosum.

Fig. 22. The stamen of Vaccinium amœnum: *a*, the pores by which the anther bursts.

Fig. 23. The anther of Begonia Evansiana: *a*, the oblique immersed cells; *b*, the connectivum.

Fig. 24. Anther of Cucumis sativa: *a*, seen from the front; *b*, from behind; *c*, the connectivum; *d*, the sinuous lobes of the anther.

Fig. 25. Stamen of Hermannia flammea: *a*, filament; *b*, scale to which the latter has grown.

Fig. 26. Halved stamen of Synaphea dilatata; after Ferdinand Bauer: *a*, filament; *b*, connectivum; *c*, single lobe of the anther after bursting.

Fig. 27. Stamen of Eupomatia laurina, after the same.

Fig. 28. Stamen of Cephalotus follicularis, after the same: *a*, a granular connectivum.

Fig. 29. Stamen of Pterospora Andromedea: *a*, an appendage of the anther.

Fig. 30. Stamen of Securinega nitida; the cells opening transversely.

Fig. 31. Stamen of Chloranthus monostachys: *a*, connectivum.

Fig. 32. Stamen of Eriodendron Samaüma; after Von Martius: anther sinuous and one-celled.

PLATE IV.

Figs. 1, 2, 3. Different views of the stamens and stigma of Stylidium violaceum; after Ferdinand Bauer: *a a*, anthers; *b*, a column formed by the union of their filaments; *c*, a cup-like disk, consisting of the flattened and united apices of the filaments; *d*, the stigma, the style of which is united with the column of filaments through its whole length. Fig. 1. The anthers when burst, seen in front; fig. 3. the same, from behind; fig. 2. the anthers pushed aside, so as to show the stigma.

Fig. 4. Stamen of Rhynchanthera cordata; after Von Martius: *a*, a minute membrane that separates the filament *d* from the elongated connectivum *c*; *b*, the attenuated beak-like apex of the anther, opening by a single pore at the point.

Fig. 5. Stamen of Lasiandra Maximiliana; after Von Martius: *a*, dilated bases of the two cells of the anther; *b*, pore at the apex, through which the pollen is discharged.

Fig. 6. Stamen of Glossarrhen floribundus; after Von Martius: *a*, a dilated petaloid connectivum, to the face of which the lobes of the anther adhere; *b*, the filament.

Fig. 7. Stamen of Lacistema pubescens; after Von Martius: *a*, filament; *b*, forked connectivum; *c c*, separate lobes of the anther.

Fig. 8. Stamen of Gomphrena leucocephala; after Von Martius: *a*, broad dilated two-toothed filament, bearing a linear one-celled anther.

Fig. 9. Stamen of Humirium floribundum; after Von Martius: *a*, a large tuberculated petaloid connectivum.

Fig. 10. Stamen of a species of Cryptocarya, from Chili, in which the anther opens, as in other Laurineæ, by valves that roll back when they separate: *a*, one lobe of the anther, with the valve not separated; *b*, the other lobe, with the valve in the act of rolling back; *c c*, abortive stamens, under the form of glands.

Fig. 11. Stamen of Berberis vulgaris, exhibiting the same phenomenon: *a*, valve closed; *b*, valve separated and recurved.

⁂ *All the following figures of pollen are taken, with scarcely any alteration, from Purkinje, and are drawn to the same scale, so that their relative sizes are shown.*

Fig. 12. Pollen of Stratiotes aloides.
13. Calla æthiopica.
14. Elymus sabulosus.
15. Avena latifolia.
16. Scirpus romanus.
17. Pancratium declinatum.
18. Populus alba.
19. Mirabilis Jalapa.
20. Urtica dioica.
21. Armeria fasciculata.

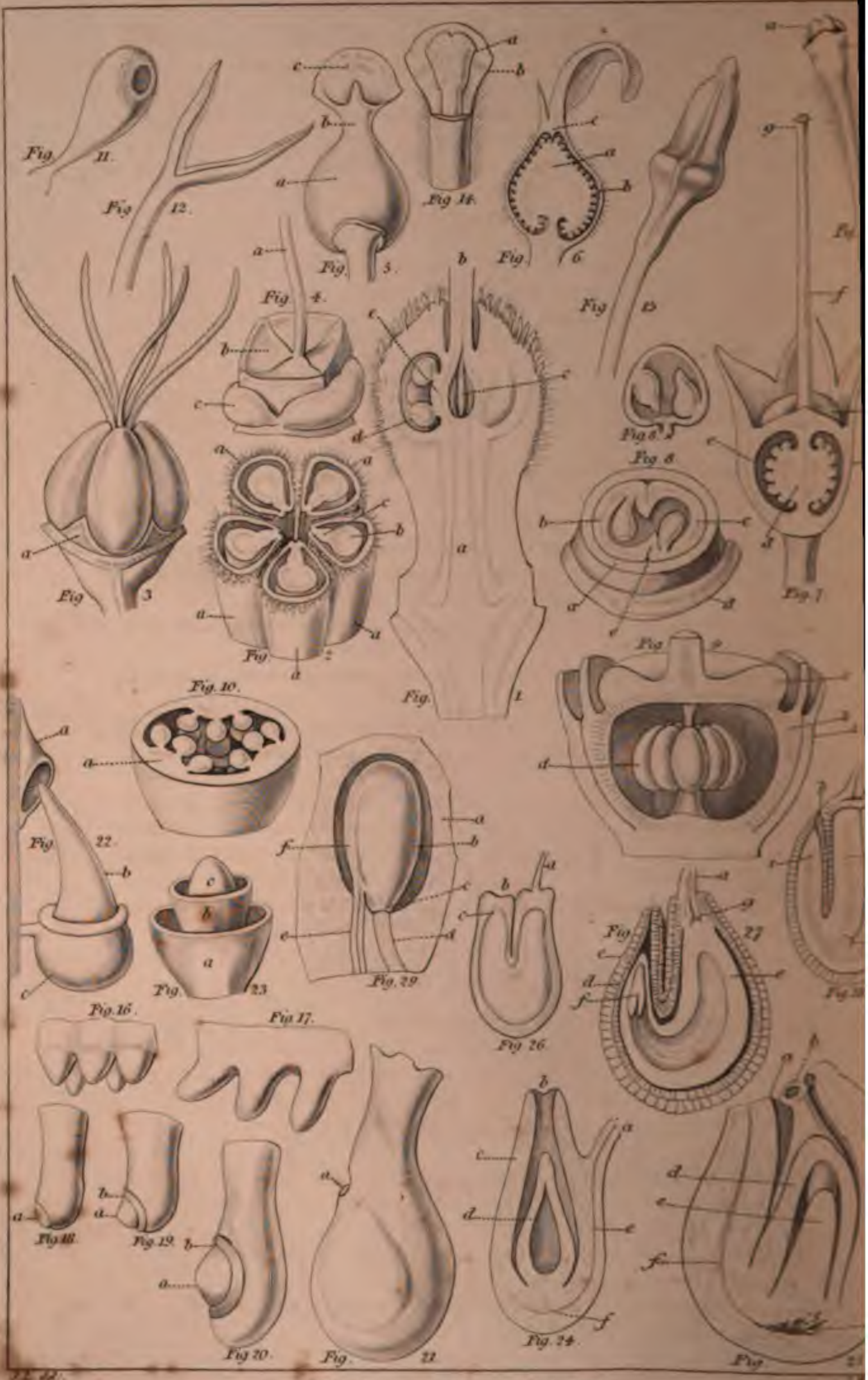

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Fig. 22. Pollen of Plumbago rosea.
23. Cineraria maritima.
24. Salvia interrupta.
25. Stachytarpheta mutabilis.
26. Polygala spinosa.
27. Heracleum sibiricum.
28. Acacia lophantha.
29. Iresine diffusa.
30. Fuchsia coccinea.
31. Scorzonera radiata.

Fig. 32. Grains of pollen of Gesneria bulbosa emitting their tubes, magnified 180 times. The tube is of extreme tenuity, and may be withdrawn from the stigmatic tissue with great facility. Masses of granular matter may be seen descending the tubes at irregular intervals.

Fig. 33. A grain of pollen of the same plant, with its tube magnified 500 times: this shows that the tube is an extension of the outer membrane of the grain of pollen, if the latter was coated by more than one. The granular matter is seen passing down the tubes, and quitting the grain of pollen, which finally becomes a transparent empty vesicle.

Fig. 34. Grain of pollen of Datura Stramonium, emitting its tube; after Brongniart: *a*, pollen-tube.

Fig. 35. Grain of pollen of Ipomœa hederacea, emitting its tube; after Brongniart: *a*, pollen tube.

Fig. 36. Mode in which the pollen acts upon the stigma in Œnothera biennis: *a a*, pollen tubes; *b b*, tissue of the stigma into which these tubes penetrate; after Brongniart,

Fig. 37. Mode in which the pollen acts upon the stigma in Antirrhinum majus; after Brongniart. The pollen sticks to the surface of the stigma, and the tubes plunge down between the utricles of cellular tissue, of which the stigma consists.

Fig. 38. A grain of pollen of the same plant with its tube, more highly magnified: *a*, the pollen tube.

PLATE V.

Fig. 1. Vertical section of the ovarium of Dictamnus albus: *a*, gynophorus, or elongated base of the ovarium; *b*, base of the style; *c*, cavity where the carpella have not united; *d*, cell; *e*, placenta, with ovula attached to it.

Fig. 2. Transverse section of the same in a more advanced state, where the carpella are beginning to separate: *a a*, carpella; *b*, an ovulum cut through; *c*, placenta.

Fig. 3. Pistillum of Coriaria myrtifolia; consisting of five carpella, each bearing a single linear stigma, and collected round a common elevated axis, the base of which is seen at *a*.

Fig. 4. Ovarium of Lamium album: *a*, base of the style; *b*, carpella pressed together into a square concave body; *c*, fleshy lobed disk.

Fig. 5. Pistillum of Pinguicula vulgaris: *a*, ovarium; *b*, style; *c*, stigma, consisting of two very unequal lobes.

Fig. 6. A vertical section of the same: *a*, the central free placenta; *b*, ovula; *c*, point where the placenta is connected, before fertilisation, with the stigmatic tissue.

Fig. 7. A perpendicular section of the pistillum of Vaccinium amœnum: *a*, inferior ovarium combined with the tube of the calyx; *b*, limb of the calyx; *c*, epigynous disk; *d*, placenta; *e*, ovula; *f*, style; *g*, stigma.

Fig. 8. A transverse section of the ovarium of Hydrophyllum canadense, showing its remarkable placentation: *a*, wall of the ovarium; *b*, left placenta; *c*, right placenta; *e*, one of their points of union, the other is seen on the opposite side; *d*, a fleshy secreting annular disk. In this case, two placentæ grow up face to face from the base of the ovarium, and gradually unite at their edges (*e*), enclosing the ovula within the cavity they thus form; this is proved by Nemophila, in which the placentation is the same, except that the placentæ are always distinct from each other; one of these placentæ, the ovuliferous face turned towards the eye, is represented at fig. 8.

Fig. 9. A perpendicular section of the inferior ovarium of Thamnea uniflora; after A. Brongniart: *a*, tube of the calyx; *b*, wall of the ovarium; *c*, epigynous disk; *d*, ovula collected round a columnar placenta.

Fig. 10. Transverse section of the ovarium of Viola tricolor, showing its parietal placentation: *a*, one of the three placentas.

Fig. 11. Stigma of the same plant, which is inflated and hollow, with an orifice obliquely situated at its apex.

Fig. 12. Bifid stigma of Chloanthes Stœchadis; after Ferdinand Bauer.

Fig. 13. Hairy apex of the style and stigma, with its indusium, of Brunonia australis; after Ferdinand Bauer: *a*, stigma; *b*, indusium.

Fig. 14. The same, divided perpendicularly; *a*, stigma; *b*, indusium.

Fig. 15. Stigma of Banksia coccinea, with a part of the style; after Ferdinand Bauer.

Fig. 16. The earliest state of the ovula of Cucumis Anguria; this, and the succeeding figures, to 25 inclusive, are after Mirbel.

Fig. 17. Three of these ovules in a more advanced state.

Fig. 18. An ovulum at the period when the apex of the nucleus (*a*) is just appearing through the primine. The foramen has already become oblique with respect to the apex of the ovulum.

Fig. 19. An ovulum of the same, at the period when the secundine is appearing through the foramen: *a*, nucleus; *b*, border of secundine; the nucleus is now more oblique than before.

Fig. 20. An ovulum of the same, at a subsequent period, but still long before the expansion of the flower; the several parts are more developed; the nucleus, which at first was terminal, has now become lateral, and is evidently turning towards the base of the ovulum: *a*, nucleus; *b*, border of secundine.

Fig. 21. An ovulum of the same, after fertilisation. In the interval between this state and the last, the primine has grown over the secundine and nucleus; the apex of the latter has turned completely to the base of the ovulum; and the foramen is contracted into the little perforation at *a*.

Fig. 22. Ovulum of Euphorbia Lathyris, in a very young state, long before the expansion of the flower: *a*, kind of cap projecting from the wall of the ovarium, and into which the apex of the nucleus (*b*) is inserted; this hood finally closes over the foramen, into which it protrudes as the nucleus retreats; *c*, the primine; the secundine is a similar cap included within the primine.

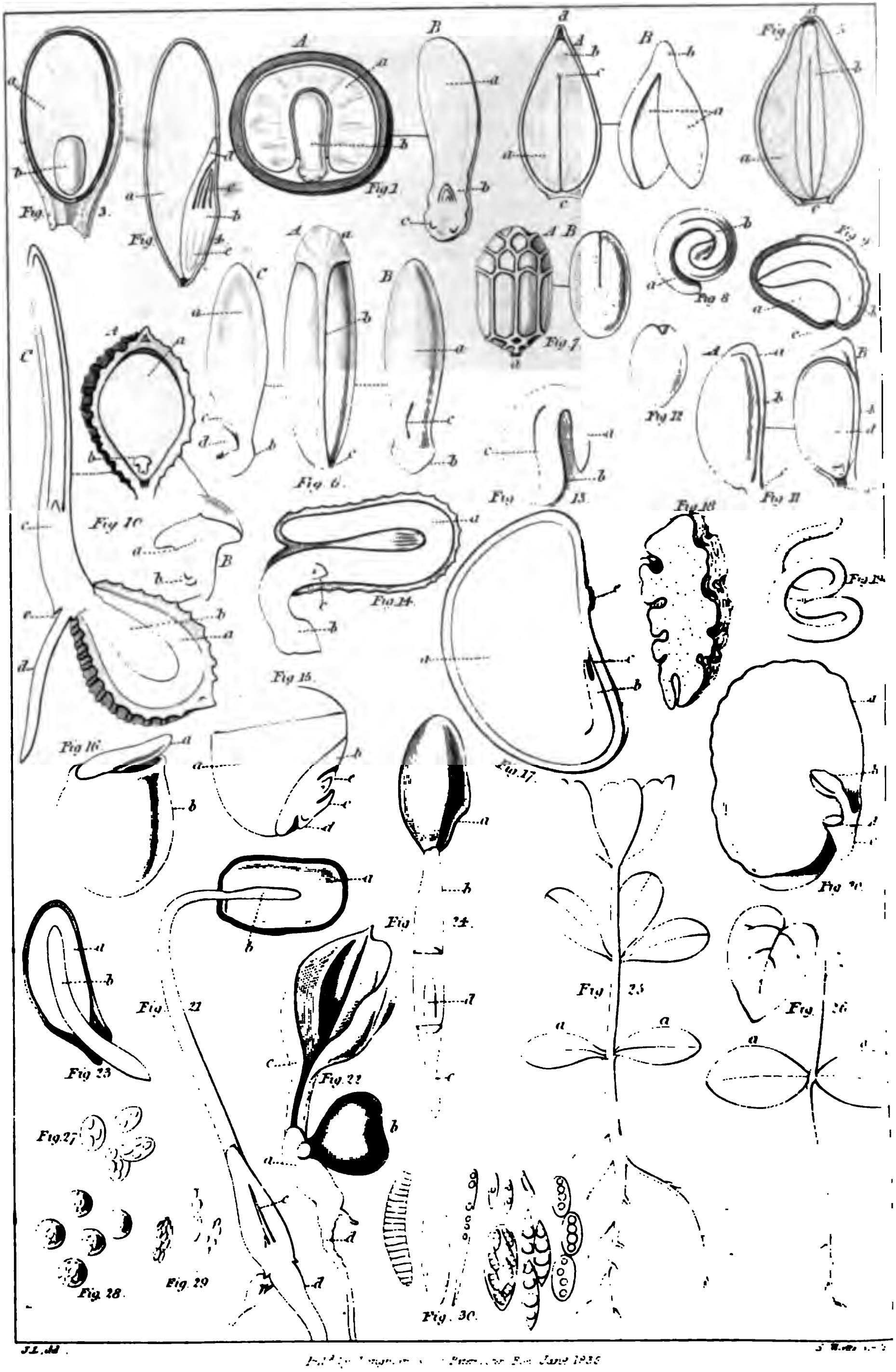

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Fig. 23. Very young ovulum of Ruta graveolens: *a*, the primine; *b*, the secundine; *c*, the nucleus. In the end, the primine extends, contracts at its foramen, and closes over the secundine and nucleus.

Fig. 24. Vertical section of an ovulum of Alnus glutinosa: *a*, the umbilical cord; *b*, foramen; *c*, primine (and secundine perhaps united with it); *d*, nucleus; *e*, vessels of the raphe; *f*, place of the chalaza.

Fig. 25. An oblique vertical section of the fertilised ovulum of Tulipa Gesneriana: *a*, foramen of the primine (or Exostome); *b*, foramen of the secundine (or Endostome); *c*, primine; *d*, secundine; *e*, nucleus, its apex concealed within that of the secundine; *f*, vessels of the raphe; *g*, place of the chalaza.

Fig. 26. Ovulum of Lepidium ruderale; after A. Brongniart: *a*, umbilical cord; *b*, foramen; *c*, point of the nucleus seen through the primine and secundine.

Fig. 27. Half-ripe seed of the same, cut through perpendicularly; after Brongniart: *a*, the umbilical cord; *b*, foramen; *c*, primine; *d*, secundine; *e*, nucleus; *f*, embryo partially formed, its radicle pointing to the foramen; *g*, the point where the nourishing vessels of the placenta expand (the chalaza).

Fig. 28. A perpendicular section of the ripe seed of the same; after A. Brongniart. The primine and secundine are consolidated, and the nucleus is entirely absorbed by the embryo. *a*, Umbilical cord; *b*, foramen, now become the micropyle; *g*, chalaza; *h*, cotyledons of the embryo; *i*, radicle; *k*, plumula.

Fig. 29. Mode of fertilisation in Cucurbita Pepo; after Adolphe Brongniart: *a*, a portion of the placenta; *b*, ovulum; *c*, its foramen; *d*, the bundle of stigmatic tissue through which the fertilising matter is conveyed, and to which the foramen is closely applied; *e*, the bundle of vessels that communicates with the umbilicus; *f*, the commencement of the raphe.

PLATE VI.

Fig. 1. A, Vertical section of the seed of Canna lutea: *a*, albumen; *b*, embryo. —B, Embryo extracted and divided vertically: *a*, cotyledon; *b*, plumula concealed within the embryo; *c*, radicle, with internal rudiments of roots.

Fig. 2. A, Vertical section of the seed of Myrica cerifera: *a*, cotyledons; *b*, radicle; *c*, plumula; *d*, remains of foramen; *e*, hilum. — B, Embryo extracted entire: *a*, cotyledons; *b*, radicle.

Fig. 3. Vertical section of the seed of Luzula campestris: *a*, albumen; *b*, embryo.

Fig. 4. Vertical section of the grain of Bromus mollis: *a*, albumen; *b*, embryo; *c*, its plumula; *d*, its cotyledon; *e*, its radicle, with internal rudiment of a root.

Fig. 5. Vertical section of the seed of Rheum rhaponticum: *a*, albumen; *b*, embryo; *c*, hilum; *d*, remains of foramen.

Fig. 6. A, Seed of Triglochin palustre: *a*, fungous chalaza; *b*, raphe; *c*, hilum. — B, Embryo of the same: *a*, cotyledon; *b*, radicle; *c*, fissure, within which the plumula lies. — C, The same halved vertically: *a*, cotyledon; *b*, radicle; c, fissure; *d*, plumula.

Fig. 7. A, Seed of a species of Begonia: *a*, hilum. — B, The dicotyledonous embryo.

Fig. 8. Coiled up embryo of Basella rubra: *a*, radicle; *b*, cotyledons.

Fig. 9. Vertical section of the seed of Mesembryanthemum crystallinum: *a*, albumen; *b*, radicle of the embryo.

Fig. 10. Anatomy of the grain, and germination of Scirpus supinus; after Richard. — A, Vertical section: *a*, albumen; *b*, embryo.— B, The embryo extracted, enlarged, and halved vertically: *a*, cotyledon; *b*, radicle. — C, The seed germinating and halved: *a*, albumen; *b*, cotyledon; *c*, plumula; *d*, young root; *e*, sheath of the latter.

Fig. 11. A, Seed of Ribes rubrum: *a*, chalaza; *b*, raphe; *c*, hilum. — B, The same, halved vertically, showing the minute embryo, with two spreading cotyledons lying at the base of the albumen: *b*, section of the raphe; *c*, hilum; *d*, albumen.

Fig. 12. Embryo of a species of Mammillaria; the cotyledons very small.

Fig. 13. Embryo of Geranium Robertianum: *a*, radicle; *b*, line of union of the two cotyledons; *c*, one of the plaits in the latter.

Fig. 14. Section of the seed of Alisma Damasonium; after Mirbel: *a*, cotyledon; *b*, radicle; *c*, plumula.

Fig. 15. Part of the seed of Olyra latifolia; after Richard: *a*, albumen; *b*, back cotyledon; *c*, front ditto; *d*, radicle; *e*, plumula.

Fig. 16. Embryo of Ruppia maritima; after Richard: *a*, plumula; *b*, cotyledon.

Fig. 17. Vertical section of the seed of Pekea tuberculosa; after Richard: *a*, radicle; *b*, collet; *c*, cotyledons.

Fig. 18. Embryo and ruminated albumen of Eupomatia laurina (a vertical section); after Ferdinand Bauer.

Fig. 19. Spiral twisted embryo of Cuscuta europæa.

Fig. 20. Half the embryo of a bean (Vicia Faba); after Mirbel: *a*, one of the cotyledons; *b*, plumula; *c*, radicle; *d*, scar from which the other cotyledon has been cut.

Fig. 21. Germination of Lachenalia serotina: *a*, albumen; *b*, cotyledon; *c*, plumula; *d*, radicle.

Fig. 22. Germination of Calla æthiopica; after Mirbel: *a*, exterior elongation of the cotyledon; *b*, seed; *c*, front leaf of the plumula; *d*, radicle.

Fig. 23. Germination of Allium Cepa: *a*, albumen; *b*, embryo elongated beyond the testa.

Fig. 24. The same further advanced: *a*, seed; *b*, base of the cotyledons; *c*, radicle or young root; *d*, plumula.

Fig. 25. Germination of Baptisia australis; after De Candolle: *a a*, cotyledons.

Fig. 26. Germination of Cercis Siliquastrum; after De Candolle: *a a*, cotyledons.

Fig. 27. Thecæ, or Sporangiola, of Erysiphe adunca; after Greville.

Fig. 28. Sporules of Phascum crassinervium; after Greville.

Fig. 29. Asci, or Thecæ, of Sphæria tubæformis; after Greville.

Fig. 30. Thecæ of various Lichens; after Von Martius.

Index.

In this Index the numbers refer to the pages. Those numbers which are preceded by a * indicate the page where the subject referred to is most copiously treated of; the other references are either incidental or less important.

ABBREVIATIONS, *499, 503.
Abnormal, 455.
Abruptè pinnatus, 464.
Absolute, 255.
Acaulis, 85.
Accisus, 460.
Accrete, 490.
Accumbent, 256.
Acerosus, 456.
Acetabuleus, 453.
Acetabuliformis, 453.
Acetic acid, in seeds, 361.
Achænium, 234. 236.
Acicula, 153.
Aciculated, 468.
Acid, acetic, in seeds, 361.
——, carbonic, in seeds, 359.
——, prussic, 424.
Acies, 449.
Acinaciformis, 449.
Acinus, 227, 228.
Acotyledons, 250.
Acrogens, 260.
————, compound organs in, 258.
Acrosarcum, 240.
Aculeatus, 468.
Acuminatus, 459.
Acuminose, 459.
Acute, 459.
Acute-angled, 449.
Adductores, 266.
Adelphia, 173.
Adherent, 164.
Adhering, 490.
Adhesion, mode of, 489.
Adnascentia, 83.
Adnascens, 77.
Adnata, 83.
Adnate, 178. 275. *490.
Adnatum, 77. 83.
Adversus, 488.
Æqualivenium, 132.
Æquatus, 468.
Æquilaterus, 458.
Æruginosus, 479.
Æstivation, 152.
Aggregate, 234. 237.
Aggregatus, 493.
Aiguillons, 65.
Air-cells, *39. 91. 301.
Akena, 240.
Akenium, 236. 240.
Alæ, 168.
Ala, *73. 170.
Alabastrus, 152.
Alabastrum, 152.
Alaris, 490.
Alatus, 451.
Albescens, 477.
Albidus, 477.
Albumen, 244. *249. 516.
Alburnum, 94.
Albus, 477.
Algaceæ, 272.
Alsinaceous, 168.
Alternate, 113. 238. *491.
Alternately pinnate, 464.
Alternative, 485.
Alutaceous, 472. 479.
Alveolatus, 467.
Amalthea, 237.
Ambitus, 455.
Amentum, 155.
Ammonia, 387.
Amnios, 246.
Amphanthium, 154.
Amphigastria, 268.
Amphigenous, 491.
Amphisarca, 234. *239.
Amphispermium, 231.
Amphitropal, 256. *489.
Amphitropous, 215.
Amplexa, 485.
Amplexicaulis, 489.
Amplectans, 489.
Amylaceous granules, 43.

Anabices, 81.
Anatropous, 215.
Anastomosing, 466.
Anastomozans, 466.
Anceps, 449.
Andræaceæ, 265.
Andrœceum, 172. 181.
Androphorum, 173.
Androus, 174.
Anfractuosus, 487.
Angienchyma, 7.
Angiocarpians, 232.
Angular, 449. *461.
Animalcules, spermatic, 558.
Anisobrious, 254.
Anisodynamous, 254.
Anisos, 474.
Anisostemonous, 474.
Annexus, 490.
Annotinus, 476.
Annual, 328.
Annulatus, 468.
Annulus, 260. 267. 275.
Anther, 172. 175.
Antheridia, 266. 269.
Anthers, 516.
Anthracinus, 478.
Anthesis, 152.
Anthocarpi, 235. 241.
Anthocyane, 434.
Anthodium, 157.
Anthophore, 211.
Anthoxanthine, 434.
Anticus, 178. 488.
Antidromal, 160.
Antitropal, 256.
Antrum, 240.
Apetalous, 169.
Apex, *127. 175. 224. 458.
Apices, 172.
Apicicircinatus, 458.
Apiculatus, 459.
Apocarpi, 234, 235.
Apocarpous, 199.
Apophysis, 267.
Apothecia, 270, 271. 273.
Appendages, 165. *468.
Appendices, 83.
Appendiculate, 165.
Appendix, 170.
Apple, 240.
Apricot-colour, 479.
Arachnoid, 60.
Arachnoides, 470.
Arbor, 72.
Arbusculus, 72.
Arbustum, 72.
Arcesthide, 241.
Arcuatus, 449.
Areolate, 468.
Argenteus, 477.
Argo, 477.
Aril, 226. 248.
Arista, 149.
Aristatus, 458.
Armeniacus, 479.
Arseniate of potash, 424.
Articulated, 490.
Articulatus, 466.
Arrangement, 491.
Arrectus, 485.
Arrow-headed, 457.
Ascending, 220. 256. 319. *486.
Ascelli, 276.
Ascens, 496.
Asci, 270. *272. 274. 276.
Ascidium, 141.
Ash-grey, 477.
Ash-greyish, 477.
Asimina, 237.
Asparagi, 72.
Asper, 60. *469.
Aspergilliformis, 466.
Aspergillus, 466.
Assurgens, 486.
Ater, 477.
Atractenchyma, 7.
Attachment, mode of, 489.
Atratus, 478.
Atropous, 215.
Atrovirens, 479.
Attenuatus, 458.
Aulæum, 166.
Aurantiacus, 479.
Aurantius, 479.
Auratus, 478.
Aureus, 478.
Auriculatus, 457.
Autocarpien, 224.
Avenium, 131.
Awl-shaped, 456.
Awn, 149.
Awned, 458.
Axes, accessory, 96.
Axe-shaped, 449.
Axil, 73. 112.
Axillary, 112. *490.
Axis, 153.
Axis, appendages of the, 110.
Axis, ascending, 69.
Axis, descending, 108.

Bacca, 227, 228, 229. 231. 235. *240.
Bacca sicca, 231.
Bacca, spurious, 230.
Bacilli, 78.
Baccate, 232. *473.
Baccaularius, 237.
Badius, 478.
Balausta, 235. *241.

Bale, 149.
Banded, 481.
Band-shaped, 455.
Barbatus, *60. 470.
Barbs, 60.
Bark, 85, 86. 88. 310.
Basal, 490.
Base, 127 224.
Basidia, 276.
Basi bracteolatum, 147.
Basigynium, 194.
Basinervia, 133.
Bassorin, 557.
Beaked, 450. *459.
Beard, 149.
Bearded, 60. 175. *470.
Bell-shaped, 452.
Bellying, 455.
Berried, 473.
Berry, 227. 240.
Bi, 495.
Biconjugato-pinnatus, 464.
Biconjugatus, 465.
Bicornis, 450.
Bidentate, 461.
Bidigitato-pinnatus, 464.
Bifariam, 493.
Bifarius, 492.
Biferus, 475.
Bifidus, 461.
Bifoliolate, 464.
Biforines, 43.
Bifurcate, 175.
Bigeminate, 465.
Bigeners, 349.
Bijugus, 138. *465.
Bilobus, 461.
Bimestris, 476.
Binatus, 464.
Bini, 495.
Binodal, 160.
Bipartitus, 462.
Bipennatiparted, 138.
Bipennatisected, 138.
Bipinnate, 465.
Bi-polymorious, 152.
Biserrate, 461.
Biserialis, 493.
Biternate, 465.
Bitten, 109. 460.
Black, 478.
Blades, 112.
Bladdery, 454.
Blastema, 250. 270.
Blastus, 253.
Blatt, 112.
Bletting, 356.
Blotched, 481.
Blue, *479, 480.
Blunt, *459, 460.
Blunt with a point, 459.
Blurred, 482.
Boat-shaped, 449.
Bony, 472.
Bordered, 481.
Bossed, 447.
Botanical drawing, 544.
Bothrenchyma, *21. 107. 298.
——————, articulated, 21.
——————, continuous, 22.
Botuliformis, 454.
Bourrelet, 39.
Bouton, 52.
Brachialis, 474.
Brachiate, *72. 488.
Brachium, 474.
Bracteæ, 515.
Bracts, *146. 152. 330.
Bractlets, 147.
Branched, 465.
Branches, 71.
Brick-colour, 480.
Bright brown, 478.
Bright red, 480.
Bristle pointed, 458.
Bristles, 60.
Bristly, 468.
Brown, 478.
Brown red, 480.
Brunneus, 478.
Brush shaped, *453. 466.
Buckler-shaped, 447.
Bud, scales of, 76.
Bulb, 74. 76.
———, naked, 78.
———, solid, 77. 81.
———, tunicated, 77.
Bulbilli, 78.
Bulbotuber, 81.
Bulbulus squamosus, 78.
Butterfly-shaped, 168.
Byssaceous, 466.

Cachrys, 227. 241.
Caducous, 328. 476.
Cæruleus, 480.
Cæsious, 471.
Cæsius, 480.
Cæspitose, 492.
Cætonium, 149.
Calamus, 84.
Calathis, 157.
Calathium, 157.
Calcar, 69.
Calcareus, 477.
Caloric, disengagement of, 330.
Calybio, 239.
Calycinalis, 149.
Calyculus, 147.
Calyptra, 266.

Calyptrate, 163.
Calyx, 149. 151. *161. 515.
—— calyculatus, 147.
—— communis, 147.
—— inferior, 164.
—— liberus, 164.
superior, 164.
Cambium, 91.
Campanaceus, 452.
Campaniformis, 452.
Campanulate, 167. *452.
Campylotropous, 214, 215.
Canaliculatus, 449.
Cancellate, 467
Candidus, 477.
Canescens, 477.
Canus, 477.
Caudex, 108.
——, ascendens, 70.
——, intermedius, 70.
Cap, 274.
Capillamentum, 174.
Capillaris, 450. * 474,
Capillitium, 276.
Capillus, 474.
Capitatus, 460.
Capitulum, 156, *157, 158. 175.
Capreolus, 140.
Capsella, 230.
Capsula circumscissa, 238.
—— siliquiformis, 238.
—— tricocca, 237.
Capsular, 232.
Capsule, 175. 227, 228, 229, 230. 235. *238. 260. 263. 266.
—— spurious, 230.
Carbonic acid in seeds, 359.
Carbonic oxide, 387.
Carcerular, 232.
Carcerulus, 234. 237.
Carina, 68.
Carinatus, 449.
Cariopsis, 237
Carmine, 480.
Carneus, 480.
Carnosus, 472.
Carpadelium, 240.
Carpels, 198.
Cartilaginous, 472.
Carunculæ, 247.
Caryophyllaceous, 168.
Caryopsis, 234. 237.
Cassideous, 168.
Cataclesium, 241.
Catapetalous, 167.
Cathedrus, 140.
Catkin, 155. 158.
Catulus, 155.
Caudatus, 459.
Caudex repens, 84.
Caulicule, 250.
Cauliculi, 72.
Cauliculus, 250.
Cauline, 490.
Caulis, 84.
—— arboreus, 84.
—— deliquescens, 72.
—— excurrens, 72.
—— vimineus, 72.
—— virgatus, 72.
Caulocarpous, 475.
Cells, 193.
Cellulæ libri, 107.
—— ligni punctatæ, 107.
Cellular system, 85, *86.
Cellulose, 558.
Cenobionar, 232.
Centrifugal, 256.
Centripetal, 256.
Cephalanthium, 157.
Cephalodium, 271.
Ceraceus, 472.
Ceratium, 235. 238.
Cereus, 472.
Cerinus, 479.
Cerio, 237.
Cernuus, 487.
Cervinus, 479.
Cervix, 84.
Chaff of the receptacle, 148.
Chaffy, 470.
Chalaza, 215. 247.
Chalk-white, 477.
Channelled, 449.
Characters of classes, 526.
—— of genera, 526.
—— of orders, 526.
——, specific, 526.
Chartaceus, 471.
Chestnut-brown, 478.
Chlorine, 361. 386.
Chloro, 479.
Chlorophyll, *46. 429. 433.
Chromule, *46. 429.
——, green, 429.
Chryso, 478.
Cicatricule, 113.
Cicatrisatus, 468.
Ciliæ, 59.
Ciliated, 59. *470.
Cinenchyma, *35. 301.
Cineraceus, 477.
Cinereus, 477.
Cinnabar, 480.
Cinnamomeus, 478.
Cinnamon, 478.
Circinalis, 487.
Circinate, 485. *487.
Circulation, 389.
Circumscissile, 225.

Circumscriptio, 127. *455.*
Cirrhose, 464.
Cirrhous, 458.
Cirrhus, 140.
——— corollaris, 141.
——— foliaris, 141.
——— peduncularis, 141. 159.
——— petiolaris, 141.
Cistella, 271.
Citreus, 478.
Citrinus, 478.
Cladenchyma, 7.
Clavate, 175. 447.
Clavicula, 140.
Claviformis, 447.
Claw, 167.
Clinanthium, 154.
Clinium, 210.
Clouded, 481.
Cloves, 77.
Club-shaped, 447.
Clustered, 493.
Clypeatus, 448.
Coacervatus, 493.
Coadnatus, 490.
Coadunatus, 490.
Coal-black, 478.
Coalitus, 490.
Coated, 472.
Cobwebbed, 470.
Coccineus, 480.
Coccum, 228.
Cochlear, 485.
Cochleate, 447.
Cœnobio, 237.
Cohering, 490.
Cohesion, 251.
Coleophyllum, 252.
Coleoptilum, 252.
Coleorhiza, 252.
Collectors, 195.
Collenchyma, 186.
Colour, *427. 476.
Colpenchyma, 7.
Columella, 225, 267.
Colum, 194.
Columna, 175.
Coma, 72. 147. 245.
Combinate-venosus, 482.
Comb-shaped, 463.
Composition, 463.
Compositus, *463. 492.
Compound, 128. 156. *463. 492.
Compressed, 243. *448.
Conceptacles, 260, 261.
Conceptaculum, 227. 235. 238.
Conduplicate, 484.
Conduplicativa, 484.
Cone, 241.
Conenchyma, 7.
Confertus, 492.
Confluens, 490.
Conglomeratus, 493.
Conical, 446.
Conidia, 271.
Coniferous wood, 97.
Coniotheceæ, *5.*
Coniocysta, 274.
Conjugatus, 464, *465.*
Connate, 121 489. 490.
Connective, 178.
Connivens, 488.
Conoidal, 446.
Continuous, 494.
Contorted, 485.
Contractibility, 296.
Conus, 241.
Convergenti-nervosus, 132.
Converginervis, 482.
Converging, 488.
Convolute, *484. 486.
Convolutiva, 484.
Coppery, 480.
Costa, 29, 30.
Costatus, 133. 482.
Coracinus, 478.
Corculum, 249.
Cordatus, 457
Coriaceous, 472.
Cork, 89.
Corky, 472.
Cormus, 77. *81.
Corn, 370.
Corneus, 472.
Corniculatus, 450.
Cornua, 170.
Cornutus, 450.
Corolla, 149. *51.* **166.* *515.*
Corollina, 149.
Corollula, 168.
Corona, 70.
——— staminea, 171.
Coronans, 490.
Corpuscula vermiformia, 34.
Corrosive sublimate, 424.
Corrugata, 484.
Corrugativa, 484.
Cortex, 122.
Corticatus, 472.
Cortina, 275.
Corymb, 156. 158.
compound, 156.
Corymbose, 156.
Cotyledons, 113. 250. *253. 256.
———, absence of, 250, 251.
———, cohesion of, 250, 251.
———, increased number of, 250.
———, inequality of, 251, 252.
Cotyliform, 453.
Coussinet, 139.

Crassus, 472.
Crateriformis, 453.
Cream-colour, 477.
Cremocarpium, 235. 240.
Crenate, 137.
Crenated, 461.
Crenelled, 137.
Crenels, 137.
Crescent-shaped, 457.
Crested, 450.
Cretaceus, 477.
Crinitus, 470.
Crispus, 461.
Cristatus, 450.
Croceus, 479.
Crowded, 492.
Crowning, 490.
Cruciate, 168.
Crusta, 272.
Crustaceous, 472.
Crypta, 39.
Cubical, 447.
Cubit, 474.
Cubitalis, 474.
Cucullatus, 454.
Culmus, 70. *84. 85.
Cunearius, 456.
Cuneatus, 456.
Cuneiformis, 456.
Cupula, 148.
Cup-shaped, 452.
Cupola-shaped, 452.
Cupuliformis. 452.
Curled, 461.
Curvative, 484.
Curved, 449.
Curve-ribbed, 482.
Curve-veined, 132.
Curvinervis, 482.
Curvinervius, 32.
Curvivenius, 32.
Cushioned, 449.
Cuspidate, 458.
Cut, 461.
Cuticle, 50.
Cyano, 479.
Cyanogen, 387.
Cyathiformis, 452.
Cyclical, 255.
Cyclosis, 347. 393.
Cylindrenchyma, 7.
Cylindrical, 446.
Cyma, 72.
Cymbiformis, 449.
Cyme, 158. 159.
—— of dicotyledons, 160.
—— of monocotyledons, 160.
Cymeus, 479.
Cynarrhodum, 234. 237.
Cyphellæ, 272.
Cypsela, 235. 240.
Cystidium, 235. 276.
Cystula, 271.
Cystulæ, 270.
Cytoblast, *19. 46. 62.

Dædaleus, 460.
Day, 476.
Dealbatus, *471. 477.
Deca, 495.
Decem, 495.
Deciduous, 328. 476.
Declinate, 174. 486, 487.
Decoloration, 416.
Decompound, 138. *463.
Decreasingly pinnate, 464.
Decumbent, 488.
Decurrent, 120. 275. *489.
Decursively pinnate, 464.
Decursivus, 489.
Decussate, 493.
Dedaleous, 460.
Deep green, 479.
Deep brown, 478.
Deflexed, 487.
Dehiscence, 225.
Deliquescens, 466.
Deltoid, 457.
Demersus, 486.
Denarii, 495.
Dendroides, 466.
Deni, 495.
Dentate, 137 461.
Denudatus, 471.
Depauperatus. 493.
Dependens, 486.
Depressed, 449. 473.
Descending, 256. 319. 486.
Descriptions, 514.
————, detailed, 527.
————, examples of, 517.
Dewy, 471.
Di, 495.
Diachyma, 122.
Diadelphous, 173.
Diagnoses, 507.
Diakenium, 240.
Dichotomus, 466.
Diclesium, 235. 241.
Dicotyledons, 250.
Dicotyledonous embryo, 250.
Didymus, 466.
Didynamous, 174.
Dieresilian, 232.
Dieresilis, 237.
Diffuse, 488.
Digestion, 372.
Digitaliformis, 453.
Digitatus, 462.

Digitato-pinnate, 464.
Digitinervius, 133.
Dimidiate, 966.
Dimidiatus, *451. 458.
Diploe, 122.
Diplotegia, 235 *240.
Dipterus, 451.
Direction, 255. 483. *485.
———, special, 414.
Directè venosus, 133. *482.
Disappearing, 466.
Discoidal, *448. 481.
Discus cyathiformis, 192.
Dissected, 137.
Dissepiments, 204.
———, spurious, 206.
Disk, 92. 516.
Distant, 494.
Distichous, 492.
Distinctus, 490.
Distractile, 176.
Distribution, 516.
Diurnus, 476.
Divaricating, 34.
Divaricatus, 488.
Divergence, 118.
Diverging, 134.
Divided, 196.
Division, 460.
Divisions, 137.
Dodeca, 495.
Dodrans, 474.
Dodrantalis, 474.
Dolabriformis, 449.
Dorsal, 199. *490.
Dotted, *468. 481.
Double, 494.
Double-bearing, 475.
Doubly-toothed, 461.
Down, 59.
Downy, 469.
Drooping, 487
Drupaceous, 232.
Drupe, 228, 229. 231. 234. *236.
———, spurious, 230.
Ducts, 27 *33. 301.
———, annular, 33.
———, closed, 33.
———, dotted, 21.
———, reticulated, 33.
———, scalariform, 34.
Dumus, 72.
Duodecim, 495.
Duodeni, 495.
Duplicato-dentate, 461.
——— pinnatus, 465.
——— serrate, 461.
——— ternatus, 465.
Duplicatus, 494.
Duplici, 495.
Duplo, 474.
Duramen, 93.
Duration, 475.
Dusty, 471.
Dwarf, 473.

Eared, 457.
Eborinus, 477.
Eburneus, 477.
Echinatus, 468.
Edged, 481.
Egg-shaped, 456.
Elaio-, 479.
Elasticity, 296. 298.
Elaterium, 237.
Elaters, 17. 269.
Elatus, 473.
Ell, 474.
Ellipsoidal, 448.
Ellipticus, 456.
Elytriculi, 152.
Embracing, 489.
Emarginate, 460.
Embryo, 244. *249. 516.
Embryo-buds, 79.
Embryo, direction of the, 255.
Embryo, fixed, 74.
Embryotega, 247.
Endeca, 495.
Endocarp, 224. 236.
Endogens, 32.
———, anatomy of, 107.
Endogenous structure, 85. *102.
Endophlœum, 89.
Endophyllous, 252.
Endopleura, 244.
Endoptiles, 254.
Endorhizæ, 252.
Endospermium, 249.
Endostome, 213. 404.
Endothecium, 178.
Enervis, 483.
Ennea, 495.
Ensiformis, 456.
Entangled, 494.
Entire, 135. 460.
Ephemerus, 476.
Epiblastus, 253.
Epicarp, 224.
Epidermis, *48. 89.
Epigeous, 491.
Epigonium, 269.
Epigynous, 172. 193. 491.
Epiphlœum, 68. *89.
Epiphragma, 267.
Epiphyllous, 490.
Epipterus, 451.
Episperm, 244.
Equal, 169. 458. 473.
Equal-sided, 458.

Equal-veined, 132.
Equally pinnate, 464.
——— pinnated, 138.
Equisetaceæ, 262.
Equitant, 485.
Equitativa, 485.
Erect, 485. 220.
Erosus, 461.
Erythro-, 480.
Erythrostomum, 237.
Escens, 496.
Estivation, 483.
Etærio, 234. 237.
Etærionar, 232.
Evanescenti-venosus, 482.
Even, 468.
Evenness, 467.
Evergreen, 328.
Exaltatus, 473.
Exasperatus, 469.
Excipulus, 272.
thallodes, 272.
Excurrent, 466.
Exiguus, 473.
Exintine, 189.
Exogens, anomalous, 96, *et seq.*
Exogenous, 93.
————— structure, 85, 86.
Exophyllous, 252.
Exoptiles, 254.
Exorhizæ, 252.
Exosmose, 404.
Exostome, 213.
Exothecium, 175.
Exserted, 174.
Extensibility, 296.
Extine, 188.
Extrorsæ, 178.
Extrorsus, 488.

Fading, 476.
Falcate, 449.
Falsely-ribbed, 133.
Falsinervis, 483.
Fan-shaped, 451.
Fariam, 493.
Farinaceus, 473.
Farinosus, 470.
Fasciarius, 455.
Fasciated, 481. 493.
Fascicle, 156. 158.
Fascicled, 492.
Fasciculated, 110.
Fastigiate, 493.
Faux, 167.
Favosus, 467.
Feather-veined, 134.
Feathery, 470.
Female system, 193.
Fenestrate, 238.
Fermentation, 45.
Ferns, 258.
Ferrugineus, 478.
Fertilisation, 297. 337.
Few, 494.
Fibre, 1.
——, elementary, 6.
Fibrillæ, 272.
Fibrils, 109.
Fibrous, 109. 472.
Fiddle-shaped, 457.
Filament, 174. 516.
Filiformis, 450.
Fimbriatus, 470.
Fingered, 462.
Firmness, 298.
Fissures, 137.
Fissus, 461.
Fistulous, 446.
Five-nerved, 129.
Five-ribbed, 133.
Flabelliformis, 451.
Flagella, 72.
Flagelliformis, 449.
Flagellum, 83.
Flame-coloured, 480.
Flammeus, 480.
Flavescens, 478.
Flavidus, 478.
Flavovirens, 479.
Flavus, 478.
Flax, strength of fibre of, 24.
Flesh-coloured, 480.
Flesh of vegetable bodies, 297.
Fleshy, 472.
Fleurons, 152.
Flexuose, 487.
Floating, 485.
Flocci, 275.
Floccose, 469.
Floral, 490.
—— envelopes, 330.
Florets, 152.
——— of the disk, 157.
————— ray, 157.
Flosculi, 152.
Flower, *151. 283.
Flowers, 515.
Fluid, conveyance of, 298.
Fluids, transmission of, 296.
Fluitans, 485.
Foliaceous, 451.
Folia falsinervia, 131.
—— nullinervia, 131.
Foliaris, 490.
Foliation, 78.
Foliiformis, 451.
Foliola, 171.
Foliolum, 139.
Folium bipinnatum, 138.

Folium tripinnatum, 138.-
——— venosum, 133.
Follicule, double, 238.
Folliculi, 262.
Folliculus, 227, 228, 229. 234. *236.
Food of plants, 366.
Foot, 474.
Foramen, 213.
Forked, 466.
Form, general, 446.
Fornix, 171.
Fovilla, 190.
Foxglove-shaped, 453.
Free, 164. 275.
Fringed, 470.
Frond, 268.
Fronds, 258.
Frosted, 471.
Fructus inferus, 224.
——— superus, 224.
Fruit, *221. 516.
———, aggregate, 234. 237.
———, collective, 235. 241.
———, compound, 234. 237.
———, simple, 234, 235.
———, physiology of, 353.
Fruits, spurious, 230.
Frutex, 72.
Fruticulus, 72.
Fugacious, 328. 476.
Fugax, 476.
Fulcra, 141.
Fuligineus, 478.
Fuliginosus, 478.
Fulvus, 479.
Fumeus, 477.
Fumosus, 477.
Funalis, 450.
Fundus plantæ, 70.
Fungaceæ, 274.
Fungi, their respiration, 378.
Fungiformis, 454.
Fungilliformis, 454.
Funiculus, 213.
umbilicalis, 194.
Funiliformis, 450.
Funnel-shaped, 452.
Furcatus, 466.
Furrowed, 468.
Fuscus, 478.
Fusiform, 109. *448.
Fusinus, 448.

Galacto-, 477.
Galbulus, 241.
Galea, 167.
Gamosepalous, 165.
Gamopetalous, 167.
Gelatinous, 472.
Gemini, 495.
Gemma, 73, 74.
Gemmæ, 270.
Gemmule, 250.
Generic names, 528.
———, adoption of, 531.
———, construction of, 531.
Generic and specific characters, 507.
Geniculate, 175.
Geniculatus, 487.
Geniculum, 70.
Geminatus, 494.
Germen, 193.
Germination, 250. 252. *359.
Gibbous, 447.
Gigantic, 473.
Gilvus, 479.
Gills, 275.
Githagineus, 480.
Glaber, 471.
Gladiatus, 456.
Glandular, 469.
Glandaceus, 478.
Glandes cellulaires, 67.
——— à godet, 67.
——— vasculaires, 67
——— vesiculaires, 39.
Glands, 37
———, compound, 66.
———, nternal, 66.
———, lenticular, *67. 306.
———, sessile, 67.
———, simple, 65.
———, stalked, 65.
Glandulæ, 261
——— hypogynæ, 192.
——— impressæ, 39.
——— urceolares, 67.
——— utriculares, 66.
Glans, 235. 239.
Glaucescens, 479.
Glaucous, 471.
Glaucus, 479.
Glittering, 471.
Globose, 446.
Globuli, 271.
Globuline, 44.
Globulosus, 446.
Globulus, 271.
Glochidatus, 60.
Glochis, 60.
Glomeruli, 271.
Glomerulus, 157, 158.
Glomus, 157.
Glossology, 443.
Gluma, 149.
——— exterior, 149.
——— interior, 149.
Glume, 150.
Glumella, 149.
Glumellula, 149.

Glumes, 149.
Glutinosus, 471.
Gnawed, 461.
Gnomonical, 255.
Goblet-shaped, 453.
Golden yellow, 478.
Gongyli, 272.
Gongylodes, 451.
Gongylus, 273.
Gonophore, 211.
Gonophorum, 211.
Gousse, 236.
Grafting, 135.
Grain of wood, 312.
Grammicus, 482.
Granula, 273.
Granular, 466.
Granules, 181.
Granulatus, 466.
Grass green, 479.
Greasy, 471.
Grey, 477.
Griseus, 477.
Green, 479.
Grossification, 195.
Grossus, 227.
Growing point, 73.
Grumous, 451.
Gum, 380.
Guttatus, 481.
Gymnocarpians, 232.
Gynæceum, 193.
Gynobase, 211.
Gynophore, 194.
Gynostemium, 175.
Gypseus, 477.
Gyratus, 487.
Gyroma, 260. 271.
Gyrus, 260.

Hæmatiticus, 480.
Halbert-headed, 457.
Half-netted, 467.
Half-stem-clasping, 489.
Half-terete, 448.
Halved, *451. 458.
Hairiness, 59.
Hair-pointed, 458.
Hair-shaped, 450.
Hair's breadth, 474.
Hairs, 59.
——, branched, 61.
——, divaricating, *61. 64.
——, ganglioneous, 61.
——, glandular, 60.
——, lymphatic, 62.
——, Malpighiaceous, 62.
——, moniliform, 61.
——, nodulose, 61.
——, one-sided, 61.
Hairs, pinnate, 61.
——, plumose, 61.
——, secreting, 62.
——, stellate, 60.
——, toothed, 61.
——, toothletted, 61.
——, torulose, 61.
Hairy, 469.
Hami, 60.
Hampe, 153.
Hanging down, 486.
Hastatus, 457.
Headed, 460.
Heart-shaped, 457.
Heart-wood, 93.
Heat, 361.
Hebetatus, 460.
Helicoid, 160.
Helmet, 167.
Helvolus, 479.
Hemigyrus, 236.
Hemp, strength of fibre of, 24.
Hepaticæ, 268.
Hepta, 495.
Hepaticus, 478.
Herbaceous, 473.
Herbaria, 537.
Herbarium, 537.
Hesperidium, 235. *239.
Heterocarpien, 224.
Heterocephalous, 157.
Heterogamous, 157.
Heterorgana, 391.
Heterotropal, 256.
Hexa, 495.
Hidden-veined, 134.
Hilofère, 244.
Hilum, 243. 246.
Hinoideus, 132. 483.
Hirsuties, 59.
Hirsutus, 59.
Hirtus, 469.
Hispid, 469.
Hoary, 469. 477.
Homodromal, 160.
Homogamous, 157.
Homorgana, 391.
Homotropal, 489.
Homotropus, 489.
Honeycombed, 467.
Hooded, 454.
Hook-backed, 458.
Hooked, 459.
Hooks, 60.
Horarius, 476.
Horizontal, 204. 486.
Horned, 450.
Hornus, 476.
Horns, 171.
Horny, 472.

Hortus siccus, 537.
Hour, 476.
Humilis, 473.
Humifusus, 488.
Hybernaculum, 74.
Hybrid plants, 337.
Hybrids, 349.
Hydrocyanic acid, 388.
Hydrochloric gas, 386.
Hydrogen, 379. 385.
——, sulphuretted, 386.
Hymenium, 275.
Hypanthodium, 154.
Hypha, 274.
Hypoblastus, 253.
Hypocrateriform, 167. *452.
Hypogæus, 491.
Hypogynous, 172. *491.
Hypophyllum, 140.
Hypostasis, 218.
Hypothecium, 271.
Hysteranthous, 475.

Ianthinus, 480.
Icos, 495.
Igneus, 480.
Imbricated, *484. 492.
Imbricativa, 484.
Imparipinnatus, 138. *464.
Impregnation, 344.
Inæquilaterus, 458.
Incanus, 469. 477.
Incarnatus, 480.
Inch, 474.
Incision, 461.
Incisus, 461.
Inclining, 486.
Included, 174.
Incumbent, 256.
Incurvus, 487.
Indehiscent, 224.
Indigo, 480.
Indigoticus, 480.
Indirectè venosus, 133. *482.
Induplicate, 484.
Induplicativa, 484.
Indusium, 195. 261.
Induviæ, 113.
Induviate, 113.
Inenchyma, 7.
Inermis, 468.
Inferior, 164.
Inflatus, 454.
Inflexed, 487.
Inflorescence, *152. 515.
——, partial, 159.
Infra axillary, 112.
Infractus, 487.
Infundibularis, 452.
Infundibuliform, 167. *452.
Insertion, 483. 489.
—— with respect to situation, 490.
Innate, 178. 490.
Inner bark, 88.
Innovations, 72.
Integer, 460.
Integerrimus, 460.
Integument, cellular, 88, 89.
——, cortical, 88.
——, innermost, 246.
——, outer, 245.
Integumentum externum, 219.
—— primum aut internum, 219.
—— secundum, 219.
Internode, 71.
Interrupted, 494.
Interruptedly pinnate, 464.
Intervenium, 131.
Intexine, 189.
Intine, 188.
Intoxicating gas, 388.
Intricatus, 494.
Introcurvus, 487.
Introflexus, 487.
Introrsæ, 78.
Introrsus, 488.
Introvenium, 34.
Inverted, 256. *486.
Involucellum, 147.
Involucre, *147. 262.
——, partial, 147.
——, universal, 147.
Involucrum, 261.
Involute, 252. 483. 486.
Involutiva, 483.
Irregular, 169. *455.
Irritability, 418.
Isabella-yellow, 479.
Isobrious, 254.
Isodynamous, 254.
Isos, 473.
Isostemonous, 474.
Iulus, 155.
Ivory-white, 477.

Jointed, 466.
Juba, 157.
Juga, 138.
Jungermanniaceæ, 268.
Keel, 168.
Keeled, 449.
Kermesinus, 480.
Kidney-shaped, 457.
Knee-jointed, 487.
Kneepan-shaped, 453.
Knob-like, 451.
Knotted, 450.

Lacuna, 39.

Lacunæ, 272. 301.
Labellum, 167.
Labiate, 167. 452.
Labiose, 168.
Lacerus, 461.
Lachrymæformis, 447.
Laciniated, 138.
Laciniatus, 461.
Lacinula, 169.
Lacteus, 477.
Lacunose, 467.
Lævigatus, 471.
Lævis, 471.
Lamella, 170.
Lamellæ, 275.
Lamellar, 460.
Lamina, *12. 127. 167.
proligera, 272.
Lanatus, 469.
Lanceolate, 455.
Lateral, 490.
——— ovate, 455.
Laterinervius, 132.
Lateritius, 480.
Latex, 396.
Latex granules, 47.
Laub, 112.
Lavender-colour, 480.
Laxus, *472. 492.
Layering, 84.
Lead-coloured, 477.
Leaf, 112. 180.
Leaf-buds, 73.
————, adventitious, 75.
————, latent, 75.
————, regular, 74.
————, whence generated, 297.
Leaf-like, 451.
Leafless, 127.
Leaflet, 139.
Leafstalk, *138. 490.
Leathery, 472.
Leather-yellow, 479.
Leaves, *324. 515.
———, carpellary, 115.
———, forms of, 134.
Lecus, 81.
Legumen, 227 229, 230, 231. *236.
lomentaceum, 236.
Lemon-coloured, 478.
Lenticelles, *67. 306.
Lenticularis, 447.
Lentiformis, 447.
Lentiginosus, 471.
Lens-shaped, 447.
Lepala, 181.
Lepals, 181.
Lepicena, 149.
Lepidotus, 63. *470.
Lepis, 63.
Lepisma, 192
Leprous, 470.
Less, 474.
Lettered, 482.
Leuco-, 477.
Liber, 68, 89. 490.
Lichens, 270.
Light. 372. 382. 411.
Ligneus, 472.
Ligula, 139. 145.
Ligulæ, 171.
Ligulatus, 455.
Lilac, 480.
Liliaceous, 168.
Limb, 127. 167.
Limbatus, 481.
Limes communis, 70.
Line, 474.
Linealis, 474.
Lineatus, 468.
Linear, 455.
Lined, 468.
Liquor amnios, 220.
Lirella, 271.
Little, 473.
Lituratus, 482.
Liver-coloured, 478.
Livid, 479.
Lobed, 461.
Lobes, 135.
Loculi, 175.
Loculicidal, 225.
Loculosus, 466.
Locusta, *149. 155. 158.
Lodicula, 149.
Lofty, 473.
Lomentum, 230. 234. *236.
Loose, 472. 492.
Loratus, 455.
Lorica, 244.
Lorulum, 272.
Low, 473.
Lower lip, 167.
Lunatus, 457
Lunulatus, 457.
Lupulin, 66.
Lurid, 478.
Luteolus, 478.
Lutescens, 478.
Luteus, 478.
Lycopodiaceæ, 262.
Lyrate, 463.
Lyratus, 458.
Lyre-shaped, 458.

Mace, 226.
Macrocephalous, 251.
Macropodal, 254.
Maculatus, 481.
Magnesia, 555.

Male system, 181.
Malicorium, 241.
Malleolus, 84.
Manicate, 60.
Manures, *366. 370. 559.
Many, 494.
Many-headed, 109.
Marbled, 481.
Marcescens, 476.
Margin, 127. 460.
Marginal, 490.
Marginate, 164. 481.
Margo thallodes, 272.
Marking, 467. 481.
Marks, 496.
Marmoratus, 481.
Marsileaceæ, 263.
Masked, 167.
Masses, 185.
Mealy, *470. 473.
Medulla, 249.
Medullary, 472.
———— rays, 85, 86. *92. 311.
———— sheath, *92. 309.
Meios, 474.
Meiostemonous, 474.
Mela, 477.
Melano, 477.
Melonidium, 240.
Meloniformis, 447.
Melon-shaped, 447.
Membranaceous, 471.
Membrane, 3.
————, additional, 217.
————, cuticular, 50.
Membrana interna, 219.
Membranous, 127.
Membranula, 261.
Memnonius, 478.
Meniscoid, 454.
Meniscoideus, 453.
Menstrualis, 476.
Menstruus, 476.
Merenchyma, 7. 15.
Mericarp, 240.
Merithallus, 71.
Mesocauleorhiza, 319.
Mesophlœum, 68. *89.
Mesophyllum, *122. 319.
Mesophytum, 319.
Microbasis, 237.
Micropyle, 247.
Midrib, 129, 130.
Milk-white, 477.
Mill-sail-shaped, 451.
Miniatus, 480.
Mistletoe, its germination, 408.
Mitriform, 266.
Mixtinervius, 133.
Modioliformis, 454.
Molendinaceus, 451.
Monadelphous, 173.
Moniliform, 450.
Mono-, 495.
Monocarpous, 475.
Monocotyledons, 250.
Monopetalous, 167.
Monophyllous, 165.
Month, 476.
Moria, 152.
Mosses, 265.
Mouse-coloured, 477.
Much-branched, 466.
Mucous, 471.
Mucronate, 458.
Mucus, 1.
————, organic, *1. 50.
Mules, 349.
Multi, 495.
Multiceps, 109.
Multidigitato-pinnatus, 465. .
Multiferus, 475.
Multifid, 137, 138. *462.
Multijugus, 465.
Multinodal, 160.
Multiplici, 495.
Muriatic acid gas, 386.
Muricated, 469.
Murinus, 477
Muscariform, 453.
Muscarium, 156.
Mushroom-headed, 454.
Muticus, 460.
Mycelia, 276.

Nail, 474.
Naked, 471.
———— seeds, 221. *257.
Nanus, 473.
Napiformis, 447.
Natans, 485
Natica, 247.
Naucum, 236.
Nave-shaped, 454.
Navicularis, 449.
Nebulosus, 481.
Neck, 250.
Necklace-shaped, 450.
Nectar, 170.
Nectarilyma, 171.
Nectarium, 149, 150. 170, *171.
Nectarostigma, 171.
Nectarotheca, 169.
Needle-shaped, 456.
Nervatus, 133. 482.
Nerved, 129.
Nerves, 129.
Nervosus, 482.
Netted, 132. *467.
New Zealand flax, strength of fibre of, 24.

Niger, 478.
Night, 476.
Nigrescens, 478.
Nigritus, 478.
Nitidus, 471.
Nitrogen, 379. 385. 559.
Nitrous acid gas, 386.
Niveus, 477.
Nocturnus, 476.
Nodding, 487.
Node, 70.
Nodes, artiphyllous, 71.
———, closed, 71.
———, compound, 71.
———, divided, 71.
———, entire, 71.
———, pervious, 71.
———, pleiophyllous, 71.
———, simple, 71.
Nodosus, 450.
Nodules, 79.
Nodulose, 109.
Nœud vital, 70.
Nomenclature, 528.
None, 494.
Noni, 495.
Normal, 455.
Novem, 495.
Noveni, 495.
Nucamentum, 155.
Nucleus, 77. 213, *214. 249. 272. 275.
——— proligerous, 272.
Nucula, 231. 239.
Nuculanium, 235. *239.
Nudus, 471.
Nullinervis, 483.
Nullus, 494.
Number, 494.
Numerous, 494.
Nut, 227.
——, spurious, 230.
Nutans, 487.
Nux, 228, 229. 231. 236.
—— baccata, 241.

Ob, 496.
Oblique, 134. 458. 486.
Oblong, 456.
Obtuse-angled, 449.
Obtusus, 459.
——— cum acumine, 459.
Obvolute, 484.
Obvolutiva, 484.
Ocellated, 481.
Ochraceus, 479.
Ochrea, 144, 45.
Ochre-colour, 479.
Ochroleucus, 479.
Octa, 495.
Octo, 495.
Octoni, 495.
Odours, 438.
———, fugitive, 438, 439.
———, intermittent, 438. 441.
———, permanent, 438.
Œdemata, 26.
Offset, 84.
Often-bearing, 475.
Oleaginous, 472.
Olefiant gas, 388.
Oligos-, *494, 495.
Olivaceus, 479.
Olive-green, 479.
Omphalodium, 247.
One-ribbed, 482.
One-sided, *487. 493.
Opaque, 471.
Operculate, 163.
Operculum, 142. 266.
Oplarium, 271.
Opposite, 113. 238. 488. *491.
Oppositifolii, 153.
Orange-colour, 479.
Orbicular, 456.
Orbiculus, 170. 275.
Orbilla, 271.
Organs, compound, in flowering plants, 48.
———————, in flowerless plants, 258.
Organs, elementary, *1. 296.
———————, chemical constitution of, 289.
Organs of plants, directions taken by the, 406.
Organs, spurious elementary, 37.
——— of vegetation, 146.
Orgya, 474.
Orgyalis, 474.
Orthotropal, 256. *489.
Orthotropous, 214, *215. 248.
Oscillatorius, 490.
Osseus, 472.
Ostiolum, 275.
Outline, 455.
Oval, 456.
Ovarium inferum, 164.
——— liberum, 164.
——— superum, 164.
Ovary, *193. 516.
———, inferior, 194.
———, parietal, 194.
———, superior, 194.
Ovate, 456.
Ovenchyma, 7.
Ovoidal, 448.
Ovule, *211. 516.
Ovules, 193.
———, origin of, 558.
———, structure of, 558.

Oxalate of lime, 554.
Oxide of arsenic, 424.
Oxygen in seeds, 360.

Pagina, 128.
——— inferior, 128.
——— superior, 128.
Paillette, 148.
Painted, 481.
Paired, 465.
Palaceous, 490.
Palate, 167.
Paleaceous, 164. 470.
Paleæ, 148, 149, 150.
Paleolæ, 150.
Pale yellow, 478.
Palm, 474.
Palm-veined, 137.
Palmaris, 474.
Palmate, 462.
Palmatifid, 137. 463.
Palmatilobed, 137. 463.
Palmatiparted, 137. 463.
Palmatisected, 137. 463.
Palmiformis, 483.
Palminervius, 33.
Palminervis, 483.
Palmus, 474.
Panduratus, 457.
Panduriformis, 457.
Panicle, 157, 158.
———, deliquescent, 157.
———, simple, 157.
Papery, 471.
Papillæ, 66.
Papilionaceous, 168.
Papillosus, 469.
Pappus, 163.
Papulæ, 66.
Papulosus, 469.
Papyraceus, 471.
Parabolical, 456.
Paracorolla, 171.
Parallelinervis, 132. *482.
Parapetalum, 71.
Paraphyses, 71
Paraphyllia, 144.
Parastades, 171.
Parastemon, 171.
Parastemones, 181.
Parenchyma, *9. 15.
————, thin-sided, 107.
Parietal, 194.
Pari-pinnatus, 138. *464.
Parted, 137. 462.
Partitioned, 466.
Partitions, 137.
Passages, intercellular, 37.
Patelliformis, 453.
Patellula, 271.
Patens, 488.
Pauci, 495.
Pear-shaped, 447.
Pearl-grey, 477.
Pecten, 46. 276.
Pectinatus, 463.
Pedalis, 474.
Pedate, 462.
Pedatifidus, 463.
Pedatilobatus, 463.
Pedatinervis, 483.
Pedatinervius, 133.
Pedatipartitus, 463.
Pedatisectus, 463.
Pedicels, 153.
Pediculus, 174.
Peduncle, 152, 153.
Pedunculus radicalis, 153.
Pelta, 271.
Peltate, 489.
Peltinervis, 483.
Peltinervius, 33.
Pendulous, 220. 486.
Pennatifid, 137.
Pennatilobed, 137
Pennatiparted, 137. 462, 463.
Pennatisected, 137.
Penniformis, 483.
Penninervis, 483.
Penninervius, 132. 134.
Pennivenius, 134. 137.
Penta, 495.
Pentakenium, 240.
Pepo, 229. 235. *240.
Peponida, 240.
Perapetalum, 171.
Peraphyllum, 165.
Perenchyma, 7.
Perennial, 328. 476.
Perfoliate, 121. 459.
Perforated, 467.
Perianth, 149. *162, 163.
Pericarp, 223, 224.
Perichætial, 266.
Pericladium, 39.
Periclinium, 147
Peridermis, 89.
Peridiolum, 273.
Peridium, 275.
Peridroma, 260.
Perigonium, 149. 163.
Perigynandra communis, 147.
———— interior, 166.
Perigynium, 150. 192.
Perigynous, 172. 193. *491.
Periphoranthium, 147.
Periphyllia, 149.
Peripterus, 451.
Perisperm, 244.
Perispermium, 249.

Perisporum, 150.
Peristachyum, 149.
Peristomium, 267.
Perithecium, 271. 275.
Peritropal, 488.
Permanent, 476.
Permeability, 296.
Peronate, 470.
Perpendicular, 486.
Perpusillus, 473.
Persistent, 328. 476.
Personate, 167. 451.
Perspiration, 389.
Pertusus, 467.
Pes, 474.
Petals, 166.
Petal-like, 451.
Petaloideus, 451.
Peteridium, 238.
Petioles, 112. 127. *138. 515.
———, partial, 138.
Petiolaris, 490.
Petiolules, 138, 139.
Phæo-, 478.
Phlœum, 89.
Phœniceous, 480.
Phoranthium, 154.
Phragmiger, 466.
Phycomater, 273.
Phycostemones, 192.
Phyllodium, 140.
Phylloideus, 451.
Phyllum, 163.
Physiology, 277.
Phytography, 506.
Piceus, 478.
Pictus, 481.
Pileus, 274.
Pili capitati, 61.
—— Malpighiacei, 61.
—— pseudo-Malpighiacei, biacuminati, 61.
—— scutati, 63.
—— subulati, 60.
Pilidium, 271.
Piliferus, 458.
Pilose, 163.
Pilosity, 59.
Pilosus, 59. *469.
Pilula, 227. 241.
Pimpled, 469.
Pinnate, 464.
———, with an odd one, 464
Pinnatiscissus, 462.
Pinnatifid, 462.
Pinnatilobatus, 463.
Pinnatisectus, 463.
Pistil, 5 91.
Pistillidia, 266.
Pita flax, strength of fibre of, 24.
Pitcher, 141.
Pitcher-shaped, 452.
Pitch-black, 478.
Pith, 85, *86. 88. 309.
Pithy, 472.
Pits, 5.
Pitted, 467.
Pivotante, 109.
Placenta, *194. 199. 200.
———, free central, 207.
Placenta-shaped, 447.
Plaited, 484.
Plane, 449.
Plants considered in a state of action, 277.
Plate, 92. 285.
Plateau, 81. 194.
Pleurenchyma, *22. 25. 35. 298.
Plicativa, 484.
Plopocarpium, 236.
Plumbeus, 477.
Plumose, 163. 470.
Plumule, 250. 253.
Pluri, 495.
Poculiform, 453.
Podetia, 271.
Podogynium, 194.
Podospermium, 94.
Poils en écusson, 63.
—— en fausse navette, 61.
—— en goupillon, 61.
—— en navette, 61.
Point, 458.
Point-growers, 260.
Pointless, 460.
Pointleted, 459.
Poisons, metallic, 419.
———, vegetable, 419.
Polakenium, 240.
Polexostylus, 237.
Polinaria, 269.
Polish, 471.
Polished, 471.
Politus, 471.
Pollen, 172. 175. 181. 516.
———, origin of, 182.
———, surface of, 186.
———, colour of, 190
Pollen-cells, 83.
Pollen-grain, shell of, 188.
Pollen-granules, figure of, 187.
Pollen-tube, 191.
Pollex, 474.
Pollicaris, 474.
Poly-, *494, 495.
Polyadelphous, 173.
Polycarpous, 475.
Polychorion, 237.
Polypetalous, 167.
Polyphore, 211.

Polysecus, 237.
Pome, 240.
Pomum, 228, 229. 231. 235. *240.
Porphyreus, 478.
Posticæ, 178.
Posticus, 488.
Pouch-shaped, 453.
Powdery, 471.
Præfloration, 483.
Præmorse, 109. 460.
Prasinus, 479.
Prickles, 68.
Prickly, 468.
Primine, *213. 219.
Principles, proximate, 380.
Prismaticus, 446.
Prism-shaped, 446.
Prismenchyma, 7.
Proboscideus, 450.
Procerus, 473.
Procumbent, 488.
Pronus, 488.
Propagines, 78.
Propago, 84.
Propagula, 271.
Propagulum, 84.
Prosenchyma, 15.
Prosphyses, 266.
Prostrate, 488.
Proteranthous, 475.
Protoxide of nitrogen, 388.
Pruinosus, 471.
Prussian blue, 479.
Pseudo-bulb, 84.
Pseudocostatus, 133.
Pseudohymenium, 273.
Pseudomonocotyledonous, 251.
Pseudoperidium, 273.
Pseudoperithecium, 273.
Pseudothallus, 160.
Pteris, 451.
Pterodium, 238.
Pubens, 469.
Pubes, 59.
Pubescens, * 59. 469.
Pulley-shaped, 453.
Pullus, 478.
Pulverulentus, 471.
Pulvinatus, 449.
Pulvinuli, 271.
Pulvinus, 139.
Pumilus, 473.
Punctatus, 468. 481.
Punctuation, 526.
Pungent, 458.
Puniceus, 480.
Pure black, 477.
Pure white, 477.
Purple, 480.
Pusillus, 473.
Putamen, 224.
Pygmæus, 473.
Pyramidalis, 446.
Pyrenarium, 240.
Pyridium, 240.
Pyriformis, 447.
Pyxis, 235.
Pyxidium, 234. *238.

Quadri, 495.
Quadridigitato-pinnatus, 465.
Quadrifoliate, 464.
Quadrijugus, 465.
Quadruplici, 495.
Qualities, economical, 516.
————, medical, 516.
Quartine, 217.
Quaternati, 495.
Quaterni, 495.
Quinate, 464.
Quinati, 495.
Quincunx, 485.
Quini, 495.
Quinque, 495.
Quinquefid, 137.
Quinquejugus, 465.
Quinquenervis, 482.
Quintine, 217.
Quintuple-nerved, 129. 482.
Quintuplici, 495.
Quintuplinervia, 133.
Quite entire, 460.
Quite simple, 463.

Raceme, 154. 158.
Rachis, * 153, 154. 260.
Radiant, 494.
Radiating, 133. 137.
Radiatus, 133. * 494.
Radical, 490
Radicle, *250. 253.
Radicles, 108.
Radiculoda, 253.
Radii, 156.
Ramastra, 139.
Ramealis, 490.
Ramenta, 63.
Ramentaceous, 127. 470.
Rameous, 490.
Rami, 71.
——— annotini, 476.
——— horni, 476.
——— viminei, 72.
Ramosissimus, 466.
Ramosus, 465.
Ramuli, 71.
Ramulosus, 465.
Raphe, 175. *215. 247.
Raphides, * 37. 41. 548.
Rarus, 494.

Raven-black, 478.
Receptacle, 153. 175 *210. 261.
———— of the flower, 153.
———— of the seeds, 194.
Receptacles of oil, 39.
———— of secretion, 38.
Receptaculum, 210.
Recesses, 135.
Reclinate, 485.
Reclining, 486.
Rectinervis, 482.
Rectinervius, 132.
Rectivenius, 132.
Rectus, 485.
Recurvus, 487.
Red, 480.
Red-brown, 478.
Reflexed, 134. 487.
Refractus, 487
Regma, 234. 237.
Regular, 169. 455.
Relative, 255.
Reliquiæ, 113.
Remotus, 494.
Renarius, 457.
Reniformis, 457.
Repand, 461
Replicate, 484.
Replicativa, 484.
Replum, 236.
Réservoirs accidentales, 38.
———— en cæcum, 38.
———— vésiculaires, 39.
Respiration, 372.
Restans, 476.
Resupinate, 486.
Reticulatus, 132. *467.
Reticulum, 144.
Reticulated, 129.
Retinervis, 483.
Retinervius, 33.
Retrocurvus, 487.
Retroflexus, 134. 487.
Retrorsus, 488.
Retuse, 459.
Revolute, 484. 486.
Revolutiva, 484.
Rhizina, 109.
Rhizula, 109.
Rhizocarpous, 475.
Rhizoma, 84. 250.
Rhodo-, 480.
Rhomboid, 457.
Rhytidoma, 90.
Rib, 130.
Ribbed, 133. *482.
Rictus, 167.
Right-angled, 134.
Ringed, 468.
Ringent, 167. *451.
Rope-shaped, 450.
Roridus, 471.
Rosaceous, 168. 494.
Rostella, 60.
Rostellatus, 459.
Rostellum, 250.
Rostratus, 459.
Rostrum, 170.
Rosulate, 492.
Rosy, 480.
Rotate, 167. 453.
Rotation, 391.
Rotatus, 452.
Root, *108. 304. 515.
——, creeping, 82.
Rootstock, 84.
Rotundus, 456.
Rough, 60. 469.
Roughish, 469.
Roundish, 456.
Rows, 493.
Rubellus, 480.
Ruber, 480.
Rubescens, 480.
Rubeus, 480.
Rubicundus, 480.
Rubiginosus, 480.
Rufescens, 478.
Rufous, 478.
Rugose, 467.
Rugose-terminal, 446.
Ruminated, 249.
Runcinate, 458. 466.
Runner, 83.
Ruptinervis, 482.
Ruptinervius, 132.
Rupturing, 226.
Rusty, 478.
Rutilans, 480.
Rutilus, 480.

Sac of the embryo, 217.
Saccus, 170.
Sacellus, 241.
Saddle-shaped, 454.
Saffron-coloured, 479.
Sagittatus, 457.
Salep, 557.
Salver-shaped, 452.
Samara, 228, 229. 234. *238.
Sanguine, 480.
Sap, accumulation of, 401.
——, cause of the motion of, 402.
Sarcobasis, 237
Sarcocarp, 224.
Sarcodermis, 244.
Sarcoma, 192.
Sarmentidium, 160, 161.
Sarmentum, 83.
Sausage-shaped, 454.

Sawed, 461.
Scaber, 469.
Scabridus, 469.
Scale, 148.
Scales, 149.
——— of the bud, 76.
Scaly, *470. 493.
Scape, 153.
Scapellus, 250.
Scaphium, 168.
Scapus, 250.
Scarious, 472.
Scarlet, 480.
Scarred, 468.
Scattered, 492.
Scimitar-shaped, 449.
Scleranthum, 241.
Sclerogen, 4.
Scobina, 153.
Scorpoid, 160.
Scrobiculatus, 467.
Scrotiformis, 453.
Scurf, 63.
Scutatus, 447.
Scutella, 270.
Scutelliform, 453.
Scutellum, 253. 271.
Scutiformis, 447.
Scutum, 171.
Scypha, 271.
Scyphus, 170.
Sea-green, 479.
Secretion, 372.
Secretions, amylaceous, 297.
————, saccharine, 297.
Secundine, 214. 219.
Secundus, *487. 493.
Secundinæ internæ, 249.
Seed, 224. *242. 358. 516.
——, back of, 243.
——, face of, 243.
Seeds, duration of vitality in, 358.
——, naked, 257.
——, preservation of, 364
Segments, 137.
Sellæformis, 454.
Semi-amplexa, 484.
Semi-amplexicaulis, 489.
Semi-anatropous, 215.
Semi-lunatus, 457.
Seminus, 249.
Semi-reticulatus, 46
Semiteres, 448.
Seni, 495.
Sepala, 163.
Sepals, 163.
Separate, 490.
Septa, 204.
Septatus, 466.
Septem, 495.
Septemnervia, 482.
Septeni, 495.
Septicidal, 225.
Septifragal, 225.
Septum, 175.
Serialis, 493.
Sericeus, *60. 470.
Serratus, 461.
Sertulum, 156.
Sesqui, 474.
Sesquipedalis, 474.
Sessile, 127. 139. *489.
Seta, 149. 266.
Setæ, *60. 65.
——, hypogynous, 150.
Setose, 60. 63.
Sex, 495.
Sexuality, 345.
Sextuplici, 495.
Shaggy, 469.
Sharp-pointed, 459.
Sheath, 139.
Sheathing, 139. 490.
Shields, 270.
Shield-shaped, 448.
Shining, 471.
Sigmoid, 255.
Signs, 496.
Silex, 370. 381.
Silica, 555.
Silicula, 229. 235. 238.
Siliqua, 227. 229. 231. 235. *238.
Silk, strength of, 24.
Silky, 60. 470.
Silver grain, 92. 311.
Silvery, 477.
Similary parts, 1.
Simple, 127. 156. *463. 495.
Simplici, 495.
Simplicissimus, 463.
Sinuate, 461.
Sinuolatus, 461.
Sinus, 135.
Size, 473.
Sky blue, 480.
Slashed, 138. 461.
Slate grey, 477.
Slimy, 471.
Smaragdinus, 479.
Smoky, 477.
Smooth, 471.
Snow-white, 477.
Soboles, 82, 83.
Soil, exhaustion of, 370.
Solitary, *494, 495.
Solubility, 226.
Solutus, 490.
Sooty, 478.
Soredia, 271.
Sori, 260.

Sorosis, 235. 241.
Spadiceus, 478.
Spadix, 155. 158.
Span, 474.
Sparsus, 492.
Spathe, 148.
Spathella, 150.
Spatulate, 456.
Specific characters, 526.
Spermaphorum, 194.
Spermatocystidia, 266. 269.
Spermatocystidium, 175.
Spermatic animalcules, 270. 558.
Spermidium, 236.
Spermodermis, 244.
Sphærenchyma, 7.
Sphæricus, 446.
Sphagnum pores, 547.
Sphalerocarpium, 235. 241.
Spheroidal, 448.
Spherula, 275.
Spiculate, 469.
Spike, 154. 158, 159.
——, compound, 159.
Spikelet, 149. 155.
Spilus, 247.
Spindle-shaped, 448.
Spine, 74.
Spines, 64. 69.
——— of leaves, 142.
Spiny, 468.
Spiral, 175. 447. 487. *493.
—— arrangement of parts, 113.
—— vessels, *27. 107. 299.
————, compound, 30.
————, in roots and seeds, 547.
————, simple, 30.
Spiraliter contorta, 485.
Spithama, 474.
Spithamæus, 474.
Splendens, 471.
Split, 461.
Spodo-, 477.
Spongelet, 109.
Spongiolæ seminales, 67.
Spongiole, 109.
Spongy, 472.
Spontaneous movement, 411.
Sporæ, 273.
Sporangia, 260. 262. 264. 274.
Sporangidium, 267.
Sporangiola, 275.
Sporangium, 266. 268. 275.
Spores, 260.
Sporidia, 273. 276.
Sporocarpia, 263.
Sporocarpium, 264. 268.
Sporules, 260. 266.
Spotted, 481.
Spreading, 134. 488.
Spur, 169.
Spuria, 120.
Spurs, 283.
Squama, 148.
Squamellus, 148.
Squamulæ, 149.
Squamosæ, 261.
Squamosus, 63. 470. 493.
Squarrose, 493.
slashed, 461.
Squarroso-laciniatus, 461.
Stalklets, 138, 139.
Stamens, 151. *171, 172. 515.
———, sterile, 181.
Staminidia, 266. 269.
Standard, 168.
Starch, 380. 557, 558, 559.
Starry, 60.
Starved, 493.
Stellate, 60. *466. 491.
Stelliformis, 491.
Stellulatus, 491.
Stem, 69. *84. 309. 515.
——, aerial, 80. 82.
——, creeping, 82.
——, determinate, 73.
——, external modifications of the, 80.
——, indeterminate, 73.
——, internal modifications of the, 85.
——, parts of the, 70.
——, subterranean, 80.
——, virgate, 72.
Stem-clasping, 489.
Stemless, 85.
Stephanoum, 240.
Sterigmata, 120.
Sterigmum, 237.
Stigma, 193. 196. 516.
Stimulans, 60.
Stimuli, 60.
Stinging, 470.
Stings, 60.
Stipels, 144.
Stipes, 70. 260. 274.
Stipitate, 490.
Stipulæ, 268. 515.
Stipules, 143.
Stole, 83, 84.
Stoma, 57.
Stomates, *51. 123. 279. 558.
———, numerical proportions of, on various surfaces, 56.
Stomatia, 51.
Stone, 236.
Stool, 84.
Straggling, 488.
Stragulum, 149.
Straight, 485.
Straight-ribbed, 482.
Straight-veined, 132, 133.

Stramineus, 478.
Strap-shaped, 455.
Straw, 84.
Straw-coloured, 478.
Striated, 468.
Strictus, 485.
Strigose, 64.
Striped, 481.
Striga, 64.
Strigose, 470.
Strobilus, 228. 230. 235. *241.
Stroma, 275.
Strombus-shaped, 447.
Strontian, its effects, 369.
Strophialæ, 247.
Struma, 139. 267.
Stupose, 175.
Style, 193. *195. 516.
Stylopodium, 192.
Stylotegium, 170.
Sub, 496.
Suberosus, 472.
Submersed, 486.
Subparallel, 134.
Subramosus, 465.
Subrotundus, 456.
Subulatus, 456.
Substance, 471.
Subterranean, 491.
Succisus, 460.
Succulent, 27. 472.
Sucker, 83.
Suffrutex, 72.
Sugar, 380.
Sulcatus, 468.
Sulphur-coloured, 478.
Sulphuric acid gas, 385.
Superior, 164.
Supervolute, 484.
Supervolutiva, 484.
Supra axillary, 112.
Supra-decompositus, 464.
Supra-decompound, 464.
Surculus, 83.
Surface, 128. 467.
———, lower, 326.
———, upper, 326.
Suspended, 220.
Suspensor, 218.
Sutural, 225.
Suture, 199.
Swimming, 485.
Sword-shaped, 456.
Sychnocarpous, 475.
Syconus, 235. *241.
Symmetry, 302.
Synanthous, 475.
Syncarpi, 234. 237.
Syncarpium, 234. *237.
Syncarpous, 199.
Synedrus, 140.
Synochorion, 237.
Synonymes, 534.
Synorgana dichorganoidea, 88.

Tænianus, 454.
Tail-pointed, 459.
Talaræ, 168.
Tall, 473.
Tannin, 380.
Taper, 448.
Tapering, 458.
Taper-pointed, 459.
Tapeworm-shaped, 454.
Tap-rooted, 109.
Tartareous, 473.
Tartaric acid, 555.
Tawny, 479.
Tear-shaped, 447.
Teeth, 137.
Tegmen, 149. 244.
Tegmenta, 76. *78. 145.
——— foliacea, 78.
——— fulcracea, 78.
——— petiolacea, 78.
——— stipulacea, 78.
Temperature borne by seeds, 361.
Tendril, 140.
Tephro-, 477.
Tercine, 214. 217.
Teres, 448.
Terete, 448.
Tergeminate, 465.
Terminal, 490.
Terminology, 528.
Terms, 443.
———, collective, 491.
———, individual relative, 483.
——— of qualification, 496.
Ternate, 464. 492.
Ternati, 495.
Ternato-pinnatus, 465.
Terni, 495.
Tessellated, 481.
Testa, 219. 244.
Testaceous, 479.
Testicular, 451.
Testiculus, 175.
Testis, 175.
Tetra, 495.
Tetradynamous, 174.
Tetrapterus, 451.
Texture, 471.
Theca, 175. 266.
Thecæ, 260. 262, 263.
Thecaphore, 194.
Thalamus, 154. 210. 276.
Thalassicus, 479.
Thallodes, 272.
Thallus, 268. 270. 273. 276.

Thecidium, 236.
Thick, 472.
Three-cornered, 449.
Three-edged, 449.
Three-lobed, 461.
Three-nerved, 129.
Three-ribbed, 133. 482.
Thread-shaped, 450.
Thrice digitato-pinnate, 465.
Throat, 167.
Thyrse, 157. 160.
Thyrsula, 158.
Tigelle, 250.
Tissue, bothrenchymatous, 107.
——, cellular, *9. 296.
————————, first generated, 297.
——, conducting, 197.
——, fibrous cellular, 13. 15.
——, granular woody, 22.
——, laticiferous, *35, *36.
——, membranous cellular, 13.
————————, compressed, 14.
————————, cylindrical, 15.
————————, fusiform, 4.
————————, lobed, 14.
————————, muriform, 4.
————————, oblong, 14.
————————, prismatical, 14.
————————, sinuous, 15.
————————, stellated, 15.
————————, square, 14.
————————, tabular, 15.
——, origin of, 11.
——, pitted, 21.
——, porous, 547.
——, utricular, 9.
——, vascular, 27.
——, vasiform, 21.
——, vegetable, 1.
——, vesicular, 9.
——, woody, 22.
————, genuine, 25.
————, glandular, 25.
————, strength of, 23, 24.
Tissue, woody, thick-sided, 107
Toise, 474.
Tomentose, 59. 469.
Tomentum, 59.
Tongue-shaped, 449.
Toothed, 135. 137. *461.
Toothings, 137.
Top-shaped, 447.
Torn, 461.
Torsiva, 485.
Tortuous, 487.
Torulosus, 450.
Torus, 210.
Tracheæ, 27.
Trachenchyma, *27. 35.
————, modified, 7.
Trapeziform, 457.
Tree, 72.
Tree-like, 466.
Trees, age of, calculated from the number of annual zones, 95.
——, Baobab, 96.
Tri, 495.
Tri-costatus, 133.
Triadelphous, 173.
Triakenium, 240.
Triangular, 457.
Triangularis, 449.
Trica, 271.
Trichidium, 276.
Trichotomus, 466.
Tricornis, 450.
Tridigitato-pinnatus, 465.
Tridentatus, 460.
Trident-pointed, 460.
Trifariam, 493.
Trifidus, 137. 461.
Trifoliolate, 464.
Trigonus, 449.
Trijugus, 465.
Trilobus, 461.
Trimestris, 476.
Trinerve, 133.
Trinervis, 482.
Trinodal, 160.
Triparted, 137. 462.
Tripennatiparted, 138.
Tripennatisected, 138.
Tripinnate, 465.
Triple, 495.
Triple-nerved, 129.
Triple-ribbed, 482.
Tripli, 495.
Triplici, 495.
Triplinervia, 133.
Triplinervis, 482.
Triplo, 474.
Tripterus, 451.
Triqueter, 449.
Trisected, 137.
Triserialis, 493.
Triternate, 465.
Trochlearis, 453.
Trophopollen, 175.
Trophospermium, 194.
Trumpet-shaped, 450.
Truncate, 460.
Truncus, 70.
————— ascendens, 70.
Trunk, 84.
Tryma, 235. *239.

Tuba, 195.
Tubæformis, 450.
Tubatus, 450.
Tube, 167.
Tuber, 82.
Tubercled, 469.
Tubercules, 110.
Tuberculum, *82. 271.
Tubes corpusculifères, 21.
—— poreux, 21.
Tubular, 446.
Tunic, 78.
Tunica externa, 244.
——— interna, 244.
Turbinate, 447.
Turgid, 454.
Turio, 72.
Turned backwards, 488.
——— inwards, 488.
——— outwards, 488.
Turning white, 477.
Turnip-shaped, 447.
Twin, 466. 494.
digitato-pinnate, 464.
Twining, 487.
———— to the left hand, 487.
right hand, 487.
Twisted, 485.
Two-edged, 449.
Two-lobed, 461.
Two-toothed, 461.
Tympanum, 267.

Ulna, 474.
Umbel, 156. 158.
———, partial, 156.
———, universal, 156.
Umber-brown, 478.
Umbilical cord, 94.
Umbilicatus, 489.
Umbilicus, 246.
Umbonatus, 447
Umbraculiformis, 454.
Umbrella-shaped, 454.
Umbrinus, 478.
Unarmed, 468.
Uncatus, 459.
Uncertain, 488.
Unci, 60.
Uncia, 474.
Uncialis, 474.
Uncinatus, 459.
Unctuosus, 471.
Undecim, 495.
Under-shrub, 72.
Undulatus, 458.
Unequal, 169. *458. 474.
Unequal-sided, 458.
Unequally pinnated, 138.
Unguiculate, 168.
Unguis, 167. 474.
Uni, 495.
Unicus, 494.
Unijugatus, 465.
Unijugus, 138. *464, 465.
Unilateralis, 493.
Uninervatus, 482.
Uninervis, 482.
Uninodal, 160.
Uninterrupted, 494.
Uniparous, 160.
Upper lip, 167.
Urceolus, 150.
Urceolatus, 452.
Urens, 470.
Utriculus, 228, 229. 234, *235.

Vacuæ, 147.
Vagi, 256.
Vagina, 139.
Vaginans, 490.
Vaginellæ, 63.
Vaginervis, 483.
Vagus, 488.
Valvate, 485.
Valves, 150. 175. 225.
Valvula, 150.
Variegated, 481
Variegation, 481.
Vasa contracta, 36.
—— expansa, 36.
—— moniliformia, 34.
—— opophora, 36.
—— porosa, 107.
—— propria, 38. 91. 107.
—— spiralia fibrosa, 31.
—— spiroidea porosa, 22.
Vascular system, 85. *92. 299.
Vasculum, 141.
Vaisseaux en chapelet, 21. 34.
———— étranglés, 34.
Vase-shaped, 454.
Vasularis, 454.
Vegetable jelly, 46.
Veining, 482.
Veinless, 131.
Veinlets, common, 131.
————, marginal, 131.
————, proper, 131.
Veins, 129.
——, costal, 131.
——, curved, 131.
——, external, 131.
——, primary, 130.
Veil, 275.
Velum, 275.
——— partiale, 275.
——— universale, 275.
Velumen, 59.
Velutinus, 59. 469.

Velvet, 59.
Velvety, 469.
Venation, 129.
Venosus, 133. 483.
Venous, 129.
Ventral, 199.
Ventricosus, 455.
Venulæ communes, 131.
——— propriæ, 131.
Venuloso-hinoideus, 132. *483.
——— nervosus, 132.
Vera, 120.
Verdigris-green, 479.
Vermicularis, 450.
Vermiculatus, 480.
Vermilion, 480.
Vernation, 78. 483.
———, circinate, 78.
———, conduplicate, 78.
———, convolute, 78.
Verrucæ, 67.
Verrucosus, 469.
Versatile, 178. 490.
Vertebrate, 464.
Vertical, 204. *486.
Verticillaster, 158.
Verticillatus, 491.
Verticillus, 113. 158.
——— spurius, 158.
Very small, 473.
Very straight, 485.
Vesicula, 140. 273.
——— amnios, 217.
——— colliquamenti, 246.
Vessels, strangulated, 34.
———, turpentine, 38.
———, vital, 36.
Vexillary, 485.
Vexillum, 168.
Viceni, 495.
Viginti, 495.
Villosity, 59.
Villosus, *59. 469.
Vimen, 72.
Vine, 84.
Violet, 480.
Virens, 479.
Virescens, 479.
Virgultum, 72.
Viridescens, 479.
Viridis, 479.
Viridulus, 479.
Viscid, 471.
Vis formatrix, 380.
Vitellinus, 479.
Vitellus, 246.
Viticula, 84.
Vittæ, 39.
Vittatus, 481.
Volubilis, 487.
Volva, 274.

Warts, 67.
Water, its action on seeds, 362.
Wavy, 458.
Waxy, 472.
Waxy yellow, 479.
Wedge-shaped, 456.
Wheel-shaped, 452.
Whip-shaped, 449.
White, 477.
Whitened, 471. 477.
Whitish, 477.
Whorl, 113.
Whorled, 491.
Wings, 168.
Winged, 140. *451.
Withering, 476.
Wood, origin of, 309.
Woody, 472.
Woody mass, 85.
Woolly, 469.
Worm-shaped, 450.
Wrinkled, 484.

Xantho-, 478.
Xanthophyll, 434.
Xerampelinus, 480.
Xylodium, 236.

Yearly, 476.
Yellow, 478.
Yellowish-green, 479.

Zoned, 482.

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